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Gulf Literacy: A Marine Science-Based Model of Scientific Literacy.

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**GULF LITERACY: A MARINE SCIENCE-BASED MODEL OF
SCIENTIFIC LITERACY**

A Dissertation

**Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy**

in

The Department of Curriculum and Instruction

by

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ABSTRACT

A well-established trend in science education reform is the move towards the goal of scientific literacy. Attributes of scientific literacy include: (a) understanding key concepts and pervasive principles of science; (b) understanding newspaper articles and graphics related to science issues; and (c) using scientific ways of evaluating evidence for individual and societal purposes (AAAS, 1989; Demastes & Wandersee, 1992). Furthermore, BSCS (1993) has proposed a model of biological literacy that includes four distinct levels (nominal, functional, structural, and multidimensional).

The Gulf of Mexico and its coastal environments are of great social, economic, and scientific importance. An understanding of the Gulf of Mexico in terms of its history, ecology, natural resources, economic impact, and fragility should be part of K-12 science education.

The following research questions formed the framework of this study: (1) Can a meaningful model of Gulf literacy be developed? (2) Does the model have instructional utility? (3) What level of Gulf literacy can high school students achieve using this booklet?

A model of Gulf literacy was developed through content analysis of coastal newspapers and expert interviews. A series of concept maps were produced as a conceptual framework of Gulf literacy. A curriculum guide (booklet) emphasizing graphics was developed for a two-week unit on the Gulf of Mexico. Students' development of Gulf literacy was assessed by interviews, concept mapping, and questionnaire.

Students in this study were emergent with respect to reaching a level of multidimensional literacy as described by the BSCS. Students'

conceptual understanding of the Gulf of Mexico was well founded for human impacts related to Gulf, marine animals, and trophic structure. An understanding of Gulf physiographic concepts was dependent upon what exercises the teacher actually utilized. However, physical/chemical processes were poorly understood (possibly due to teacher selection of activities and the existence of critical junctures such as the one at the concept of dead zones). Concept mapping was shown to be generative based on the addition of student supplied concepts on concept maps. In summary, use of microscale models of scientific literacy such as this Gulf literacy model may help inform the larger scientific literacy reform efforts.

INTRODUCTION

As the unified response to the need for science education reform, scientific literacy captures much attention. A current and well-established trend in science education is the move towards the goal of scientific literacy, often condensed as "science for all" (AAAS, 1989; BSCS, 1992). It is also quite different from earlier science education reform programs that selected the "best and brightest." They sought to prepare and accelerate such students for college science courses. Today we know that the "best and brightest" approach will not remedy the predicted dearth of scientists, kindle interest in science for the majority of students, or raise U.S. students' scores on standardized tests. That approach also circumvents our democratic ideals, unwittingly creating a technocratic elite that the general populace must depend on to make the Nation's environmental decisions.

What is scientific literacy? Of course there are many definitions, but common to most are such attributes as:

- (1) understanding key concepts and pervasive principles of science;
- (2) understanding newspaper articles and graphics related to science issues;
- (3) and using scientific ways of evaluating evidence for individual and social purposes. (AAAS, 1989; Demastes & Wandersee, 1992)

The Biological Sciences Curriculum Study (BSCS, 1993) has proposed a model of biological literacy that includes four distinct levels: nominal biological literacy, functional biological literacy, structural biological literacy, and multidimensional biological literacy (see Figure 1).

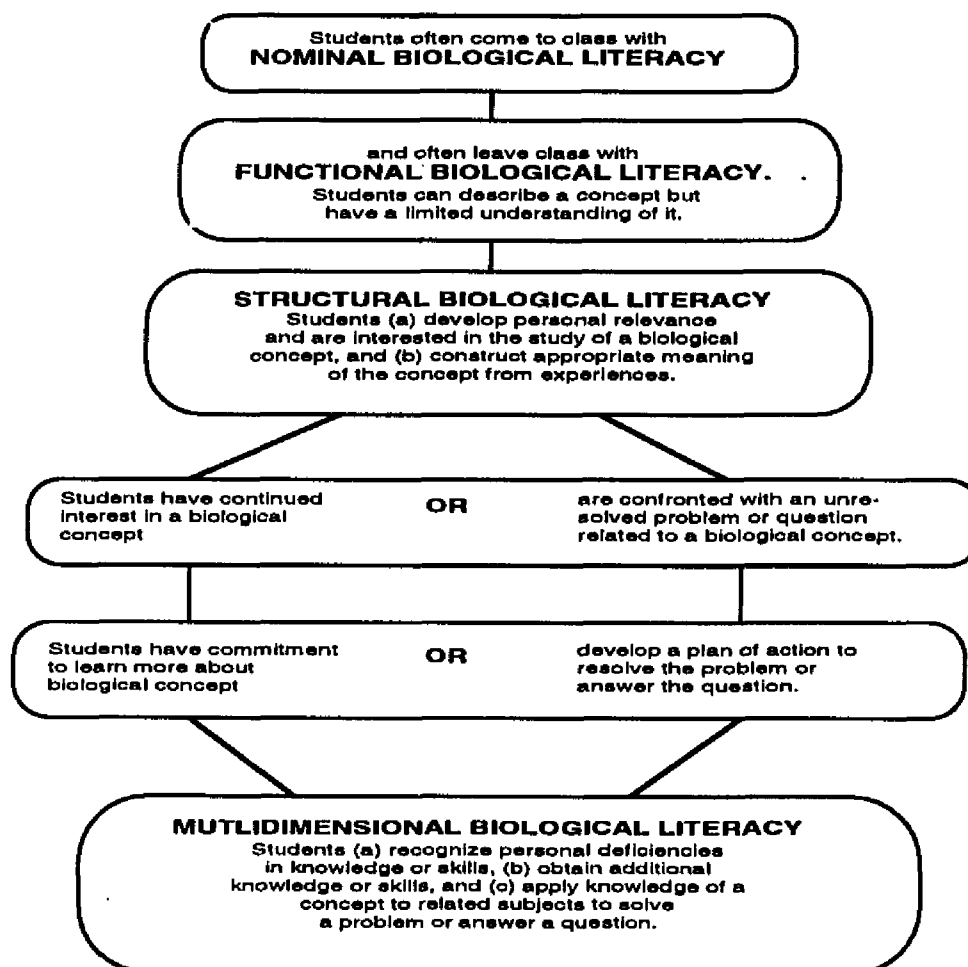


Figure 1. BSCS model of biological literacy (BSCS, 1992, P. ix).

Students who begin a biology class are typically at a nominal level and often leave that class with functional literacy, a point of limited understanding often attributable to rote memorization. At the structural level, students develop a personal relevance, interests, and appropriate meanings of concepts, based upon experiences. The last stage, multidimensional literacy, is attained when students recognize their current knowledge deficiencies and seek additional knowledge. Another characteristic of multidimensional literacy is the application of biological knowledge to solve a problem or answer a novel question.

Since the previous definition of scientific literacy requires an understanding of graphics and newspaper articles, it seemed logical that carefully chosen graphics and newspaper articles could help develop such literacy. Graphics capitalize on humans' visual learning capacities and foster visualization of scientific information. Newspaper articles may add relevance to scientific information. Personal relevance is also a key to meaningful learning.

This study asked: under the umbrella of the scientific literacy and biological literacy models, can we develop more specific working models of literacy, for example, of large marine ecosystems such as the Gulf of Mexico? The Gulf of Mexico and its coastal environments are of great social, economic, and scientific importance. The U.S. Gulf of Mexico produces 40% of the nation's commercial fish yield; it provides habitat for 75% of our migratory waterfowl; its coastal wetlands are extensive; and 90% of U.S. offshore oil and gas production occurs in the Gulf (Gore, 1992). Major hard mineral resources such as phosphate, sulfur, and sand, underexploited fishery resources, large reserves of natural gas, access to freshwater for industry and rivers for commerce signal the continuing importance of this area. The Gulf has a number of environmental problems such as overexploitation of fishery resources and habitat loss. The present and future value of these resources, as well as the fact that 1/6 of the U.S. population lives in the coastal states of the Gulf of Mexico, places this great resource in jeopardy. It can be argued that an understanding of the Gulf of Mexico in terms of its history, ecology, natural resources, economic impact, and fragility should be part of the working knowledge of coastal zone citizens and part of K-12 science education.

This study explored: What should a student who is considered to be "Gulf literate" know? Perhaps a small set of powerful and pervasive principles can be generated by searching the scientific literature, consulting with Gulf experts, examining survey data, performing a content analysis of key Gulf Coast newspapers, and searching for or creating compelling graphics that capture the student's interest. Presented here are three Gulf Literacy goals or topics as examples of possible pervasive themes this researcher hypothesized he might find;

(1) Human behavior can place the Gulf ecosystem in peril. Marine debris is not only unsightly, but is also a hazard to marine life because some animals ingest it and some become entangled in the debris, especially in plastic materials. Even worse, some of the animals that consume or get tangled in marine debris are endangered species such as the Kemp's Ridley turtle. Such animals play important roles in this large marine ecosystem -- roles which zoologists still don't fully understand. How can we stop people from generating marine debris? A nationwide beach sweep is now a much-publicized annual event. However, do people realize that debris on beaches is a symptom of a much larger problem?

(2) Pouring pollutants (i.e., used motor oil) down a storm drain within the coastal zone can have far reaching effects on the Gulf. Storm drains usually empty into a body of water that is connected to a larger body of water, eventually entering the Gulf. Drain oil, for example, often contains heavy metals, in addition to the petroleum compounds -- all of which has an impact on Gulf marine life from the tiny plankton to the top carnivores. Are people aware of the consequences of their actions?

(3) The Red Drum was harvested in the Gulf to the point where fishery stocks were unable to maintain themselves, eventually causing a

crash in the population. Management of this fishery resource has sparked conflicts between commercial and recreational fishing groups. What criteria should be used in making harvesting decisions?

The idea was not to generate a quantum of knowledge or catalog all the environmental concerns associated with the Gulf of Mexico, but to establish some consensus of priorities and to select key marine education issues, where particular scientific knowledge is vital for understanding and preserving the Gulf of Mexico as a large marine ecosystem. These topics may then guide professional practice in marine education, perhaps forming the foundation of relevant curricula. Note that the first hypothesized example allows for discussion of solid waste disposal, maritime law, and endangered species. The second example is a stimulus for nonpoint source discharge and personal decision making, such as: Where should we put our motor oil? Are there places in our community to collect it? What are the deleterious environmental effects of motor oil on the Gulf ecosystem? We hear and know of oil-spill clean-ups, but is it really cleaned up? Is it gone? Is the environment once again pristine, or at least reasonably well-restored? The last example involves such considerations as: What are the basic economics for supply and demand? How has technology helped increase fishing efficiency? How do we manage a species of fish? What are sustainable yields? What is the concept of sustainability? What kinds of resources can the Gulf of Mexico sustain for us? All of the above questions involve considering the complex interaction between scientific and technological constraints, in light of an understanding of the ecological processes that occur in the Gulf of Mexico.

At a 1992 EPA Gulf of Mexico Symposium presentation, this researcher initially proposed the "Gulf Literacy" concept and illustrated its place within the current scientific literacy reform movement of American Association for the Advancement of Science (AAAS). The term was subsequently established in print during the spring 1993 in *LSU Science Talk* 4(4) and *Current: Journal of Marine Education* 12(1) via articles by this researcher.

Definition of terms

For the purposes of this study the following definitions apply.

BSCS-- Biological Sciences Curriculum Study; a curriculum development unit in Colorado Springs, Colorado that focuses on materials for the teaching of life sciences.

Concept-- a perceived regularity in objects or events that is designated by a symbol or label.

Concept mapping-- a graphic metacognitive tool to help students learn meaningfully.

Gowin's vee-- a heuristic developed to clarify the nature and purpose of laboratory work, it relates the thinking and doing of research.

Gulf literacy model-- a working example of scientific literacy based on the understanding a large marine ecosystem, the Gulf of Mexico.

Gulf of Mexico-- a mediterranean-type sea (semienclosed, partially landlocked) lying on the western margin of the Atlantic Ocean; circumscribed by the North American continent, it is approximately 1.5×10^6 km² in size, its three bordering countries are the U.S., Mexico, and Cuba.

Large Marine Ecosystem-- (LME) any relatively large region of the world ocean, generally on the order of $\geq 200,000 \text{ km}^2$, characterized by unique bathymetry, hydrography, and productivity within which marine populations have adapted reproductive, growth, and feeding strategies (Sherman & Alexander, 1986, 1989).

Marine science-- the science pertaining to the oceans and seas.

Meaningful learning-- learning that involves the deliberate assimilation of new concepts and propositions into existing cognitive structures, with a resulting change in those structures.

Research Questions

1. Can a meaningful model of Gulf literacy be developed?
 - A. How can a content analysis of coastal zone newspapers inform this model?
 - B. How can expert knowledge inform this model building?
2. Does the resulting model have instructional utility?
3. What level of Gulf literacy can high school students achieve using the model-based instructional booklet?

A Gowin's vee was prepared as an overview of this research (see Appendix A). The vee shows the research questions, events, and data transformations, as well as the knowledge and value claims which may result from the research. The left side shows the system of concepts, principles, theories, and world views that constitute the framework of this research.

Limitations

It is recognized that qualitative methods such as interviewing techniques typically employ a small number of subjects (here students or teachers were used). The data qualitative methods provide are rich and thick with information. The researcher must decide what strands to follow and what to follow-up on immediately or at another time. To substantiate assumptions made from the verbal data, a written instrument and concept mapping were used.

In this study the researcher was very much a part of the model of Gulf literacy. There was no way to be totally objective. His intrinsic motivation and experience in this area are very much reflected in the conceptual model as well as the booklet. However, many other experts and advisors were involved to insure a community-based consensus about the model and the instructional booklet.

LITERATURE REVIEW

Theoretical Base for Research

Scientific Literacy

A distinguished senior member of the science education community, Paul DeHart Hurd, was one of the first to use the term scientific literacy in an article entitled "Scientific Literacy: Its Meaning for American Schools" in the year 1958 (DeBoer, 1991). Hurd's description of scientific literacy was an understanding of science, its application to our social experience, and that science is predominant in today's society. In 1963, scientists and science educators were questioned about the meaning of the term scientific literacy and how they felt it could be increased. The majority focused on developing greater content knowledge in a broad range of science fields. Notably, only a few of those queried considered the relationship between science and society (DeBoer, 1991). A respondent to that survey, Hugh Odishaw, executive director of the Space Science Board of the National Academy of Science, stated that scientific literacy can be defined as a comfortable familiarity with the development, methodology, achievements, and problems of the principal scientific disciplines. He stated, "A thoughtful reading of some fifty books could establish such familiarity." Koelsche (1965) identified 175 science principles and 693 science vocabulary words that constitute desirable subject matter for scientific literacy. Early definitions strongly emphasized increasing content and seemed to foster more rote memorization.

Pella, O'Hearn, and Gale (1966) and Pella (1967) conducted a content analysis seeking references to scientific literacy in the *Readers Guide to Periodical Literature 1946-64*, *American Journal of Physics*,

Physics Today, Science, Scientific American, The Science Teacher, and a card catalog. Referents that were used most frequently include:

1. Interrelations between science and society
2. Ethics of science
3. Nature of science
4. Conceptual knowledge
5. Science and technology
6. Science in the humanities

At that time in the Nation's history, the motivation behind science education funding and projects was national security. Certainly, other than cold war paranoia, the national pride suffered a blow when the Soviets were first in space. Society also held that science was going to solve every problem that came along. A 1961 article in *Vogue Magazine*, "Are You Illiterate About Science?" stated that within a decade we would be designing plants and animals genetically and science would have great social power that would be as beneficial and as dangerous as atomic energy. While literacy was given lip service, it seems the real goal was to produce more scientists.

Hurd (1970), still promoting scientific literacy, stated that science should be taught in a wider context than the processes and concepts of which it is formed, that aesthetic and social values should also be taught. According to Hurd, the social context was the appropriate context for science teaching. The National Science Teachers Association, in a 1971 position statement, stated "The major goal of science education is to develop scientifically literate and personally concerned individuals with a high degree of competence for rational thought and action" (p. 47).

Current Definitions of Scientific Literacy

There are currently a large number and variety of definitions of scientific literacy and these may vary, because an author's perception of the nature of science may include or exclude human and historical contexts of science development (Champagne, Lovitts, & Calinger, 1989). Most definitions share an essence that makes it clear enough for large-scale agreement. In *Science for All Americans* (AAAS, 1989), a basic belief is stated:

Science for All Americans is based upon the belief that the scientifically literate person is one who is aware that science, mathematics, and technology are independent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (p. 4)

The American Association for the Advancement of Science (1990) conducted a national survey asking scientists, teachers, students, and science policy analysts to rate the importance of 15 capabilities and attitudes of high school graduates for scientific literacy. The top four rated capabilities were:

1. Read and understand articles on science in the newspaper.
2. Read and interpret graphs displaying scientific information.
3. Engage in a scientifically informed discussion of a contemporary issue (e.g., Should a child with AIDS be allowed to attend public school?).
4. Apply scientific information in personal decision making (e.g., atmospheric ozone depletion and the use of aerosols).

The bottom five rated capabilities were:

1. Provide scientific explanation for a natural process (e.g., photosynthesis, digestion, combustion).
2. Assess the methodology of an experiment.
3. Define basic scientific terms (e.g., DNA, molecule, electricity).
4. Design an experiment that is a valid test of a hypothesis.
5. Describe natural phenomena (e.g., phases of the moon).

Another definition for scientific literacy came from Yager (1989), a science educator. Yager believes that scientific literacy is part of cultural literacy because a truly literate person in today's world must understand the use of science and technology in the culture. Yager promoted Project Synthesis by stating that such a program would produce scientifically literate students prepared to make decisions in a technological society.

Scientists Hazen and Trefil (1990, p. xii) wrote:
 Scientific literacy constitutes the knowledge you need to understand public issues. It is a mix of facts, vocabulary, concepts, history, and philosophy. It is not specialized stuff of the experts, but the more general less precise knowledge used in political discourse. "If you can understand the news of the day as it relates to science, if you can take articles with headlines about genetic engineering and the ozone hole and put them into meaningful context - in short, if you can treat news about science in the same way that you treat everything else that comes over your horizon, then as far as we are concerned you are scientifically literate."

From a geoscience perspective, Mayer and Armstrong (1990) proposed a curriculum to promote the scientific literacy of 17-year-olds. They described scientific literacy as follows:

Scientific thought: Every citizen will be able to understand the nature of scientific inquiry.

Knowledge: Each citizen will be able to describe and explain earth processes and features and anticipate changes in them.

Stewardship: Each citizen will be able to respond in an informed way to environmental and resource issues.

Appreciation: Each person will be able to develop an aesthetic appreciation of the earth.

Project 2061

Project 2061 is the long-term effort by the American Association for the Advancement of Science to spearhead the reform of science, mathematics, and technology education (AAAS, 1989). The number 2061 is the year in which Halley's comet will return to view on the earth; the project began in 1985, the last appearance of the comet. The project's name comes from the realization today's school children will live to see the comet return in the year 2061 and will be the adults who greatly influence life on earth--for good or for ill. Long-term reform effort is imperative.

The first phase of the project was to establish a conceptual base for such reform by identifying the knowledge, skills, and habits of mind that all students should have acquired before they finish high school. This process has produced six reports. Five reports were panel reports done by independent scientific panels. The last report cut across all of science, mathematics, and technology to summarize the project and is called *Science for All Americans* (SFAA).

Phase II (current) involves teams of educators and scientists transforming SFAA into alternative curriculum models for the use of school districts and states. During this research and development (R&D) phase, the project is drawing up blueprints and benchmarks for reform related to: (a) the education of teachers; (b) materials and technologies for teaching and testing; (c) the organization of schooling; (d) educational

policies; and (e) educational research. Furthermore, it seeks to enlarge the pool of experts in science curriculum reform and to continue to publicize the need for nationwide scientific literacy. There are six R&D sites in the U.S., each with a team of educators that includes 5 elementary teachers, 5 middle school teachers, 10 high school teachers, 3 principals, and 2 curriculum specialists. Other than the R&D sites, there are other school systems that use SFAA as a basis for their curricular reforms (states such as California, Maryland, and Michigan).

Project 2061 recommends topics that differ from traditional science topics by trying to soften the boundaries between disciplines and by emphasizing the connections between them. For example, transformations of energy occur in physical and biological systems. Another difference is in the amount of detail students are expected to learn (considerably less than traditional, vocabulary-driven science courses).

Project 2061 also recommends topics not included in traditional courses such as the nature of scientific enterprise, and how science, mathematics and technology relate to one another and to the social system we have. The AAAS also strives for basic knowledge of many of the most important episodes in the history of science and technology, as well as the major conceptual themes that run through almost all scientific thinking.

Biological Literacy

Biological literacy is a subset of scientific literacy. A definition of biological literacy was suggested by Wandersee (1991) and Demastes and Wandersee (1992): to understand a small number of pervasive biological principles and to apply them in appropriate ways when reading a newspaper, engaging in a discussion, seeking valid biological information, interpreting published tables and figures, and making personal and societal

decisions. It was suggested that biological educators pare down the content and supply students with more opportunities to build deeper understanding.

The National Science Foundation supported the BSCS effort to develop a set of recommendations bringing continuity and cohesion to the many goals of biology education. Their efforts resulted in the publication of *Developing Biological Literacy: A Guide to Developing Secondary and Post-Secondary Biology Curricula* (BSCS, 1993). In this document, BSCS makes the following recommendations: (a) the content of biology must be unified by the theory of evolution; (b) biology classes must provide opportunities for students to experience science as a process and to understand science as a way of knowing; and (c) curricula should help students develop biological literacy. It further proposes a model of biological literacy in four levels as described earlier (see Figure 1). It states that in the development of structural and multidimensional literacy, personal interest is the key. It is claimed that this may be stimulated through confrontation with personally relevant local, regional, or global biological issues.

Characteristics identified by BSCS that a biologically literate individual should have include:

- **Understand**

1. Biological principles and other major concepts of biology;
2. The impact of humans on the biosphere;
3. The processes of scientific inquiry;
4. Historical development of biological concepts.

- **Develop Appropriate Personal Values Regarding**

1. Scientific investigations;

2. Biodiversity and cultural diversity;
3. The impact of biology and biotechnology on society;
4. The importance of biology to the individual.

• **Be Able To**

1. Think creatively and formulate questions about nature;
2. Reason logically and critically and evaluate information;
3. Use technologies appropriately;
4. Make personal and ethical decisions related to biological issues;
5. Apply knowledge to solve real-world problems.

The Gulf of Mexico and Marine Education

How can a Gulf literacy model address those characteristics? The scientific literature contains abundant references to the Gulf of Mexico; most are technical and focus on a narrow aspect of concern. The *American Zoologist* (Fingerman, 1990) published the papers of a special session on the Gulf of Mexico presented at the American Society of Zoologists' annual meeting held in December of 1987. This set of papers comprises a good survey of Gulf fauna and ecology. There are also several government agencies (such as the U.S. Fish and Wildlife Service, Minerals Management Service, Army Corps of Engineers and EPA Gulf of Mexico Program) that have shelves of unpublished reports on various aspects of the Gulf of Mexico. The Gulf of Mexico Program identified eight high priority environmental problems. They are:

1. Marine debris
2. Public health
3. Habitat degradation
4. Coastal and shoreline erosion

5. Nutrient enrichment
6. Toxic substances and pesticides
7. Freshwater inflow
8. Living aquatic resources.

Committees were established to determine the status and trends of these issues related to the Gulf of Mexico. Each of these committees has produced action agendas which are periodically updated (Gulf of Mexico Program, 1991, 1992, 1993a, 1993b, 1993c, 1993d, 1993e, 1993f, 1993g).

In addition, there are some general references, often less technical, that inform us about the Gulf of Mexico. A recent book by Robert Gore (1992), *The Gulf of Mexico* is a one-stop overview of its history, geography, biology, and associated environmental concerns. The Audubon Society's *Field Guide to Atlantic and Gulf Coasts* (Amos and Amos, 1985) is also a good general reference. For an overview of North Gulf communities, *Shore Ecology of the Gulf of Mexico* (Britton and Morton, 1989) is especially useful. The National Marine Educators Association recently published a special issue of its journal on the Gulf of Mexico (Current 12[1]). *The Gulf Coast* (Lockwood, 1984) is also a good overview of the Gulf and is enhanced by superb photography.

A great deal of informal education occurs in areas surrounding the Gulf of Mexico, as well as in its marine environment. While such marine education can certainly take place anywhere, there are notable facilities and locations. In the U.S., starting from the west with Texas, University of Texas Marine Laboratory at Port Aransas, Texas State Aquarium in Corpus Christi, and Texas A&M University (which conducts activities out of Galveston) should be highlighted. In Louisiana, Louisiana Universities Marine Consortium (LUMCON), Louisiana State University Sea Grant

Program, and the Aquarium of the Americas are active sites of marine education. Mississippi supports the J.L. Scott Marine Education Center in Gulfport and Alabama has programs in Mobile and at Dauphin Island Sea Lab. Florida has many small sites, but the larger ones are Motte Marine Lab, and soon to open, the Florida Aquarium. Many such centers provide extensive field trips as well as vessel-based experiences.

Marine education programs are often identified by their location or by the people who developed them. Some programs are designed to support state curriculum guides or just to educate about the unique setting in which they find themselves. Larger freshwater education programs (such as Project Aquatic Wild and Project Wet) also have marine components. A large set of marine science curriculum materials (grades 1-12) disseminated through the National Diffusion Network were developed by Marine Science Project: For Sea (Kolb, 1986). These materials have been used extensively in Louisiana by the Louisiana State Department of Education.

Being a marine educator at a site or in a program offers unique opportunities. First, most programs emphasize field experiences so part of the job must be carried out in the marine environment. If the marine educator's program is at a field station or marine laboratory, then one has access to research vessels, laboratories, and equipment that is not part of the normal land-based school setting. It certainly lends itself to creativity. Most programs are not tied to a curriculum, so there is a large amount of freedom in selecting organisms and topics to study. The down side is that many programs are operating without a curriculum or guiding philosophy, emphasizing the need for an overarching concept like Gulf literacy.

Such a program can also be adaptable to a wide range of student or client needs. Adaptability also means that new and current topics can be brought into the program without the time delays normally associated with textbooks and rigid curriculum guides. Since student/client visits may be short, the marine educator should make use of good graphics and displays that allow people to grasp knowledge of a concept visually. The range of methods available to accomplish educational goals at marine education centers is much wider in scope than in conventional educational settings.

Unique features of marine education centers include access to working marine science laboratories and laboratories with resident equipment for students to use. This is especially noteworthy because the National Science Teachers Association (NSTA) and the National Association of Biology Teachers (NABT) have issued recent position statements urging the increased use of laboratories in science education. Another unique feature is the demonstration of interdisciplinary study. Marine science crosses the boundaries of geology, physics, chemistry, and biology. Here students/clients can see the integration of knowledge which is necessary to understand marine systems.

The roots of formal marine education can be traced back to Harvard ichthyologist Louis Agassiz who conducted summer courses for teachers on the East coast. His philosophy was not to use a text, but to study nature from nature. Several of his students went on to conduct other summer courses for teachers at different coastal locations. The recent history of marine education is intertwined with science education reform and environmentalism.

After Sputnik, when NSF money was abundant, more and more marine labs were built. Previous to that time, the development of marine

labs was quite slow. Almost every marine lab that opened in this country was built initially to provide a field station for college courses and field trips. Eventually teaching took a back seat to research, where the big grant money was. About 25 years ago, there was a rise in popular concern for our environment and the ultimate harm or destruction that could happen if present environmental practices continued. A great deal of this attention was focused on the marine environment, and it centered on ocean dumping, endangered marine mammals, coastal erosion, and the decline of fishery stocks.

Large public parks (like Sea World) and public aquaria started to appear. About 20 years ago, the Congress authorized the College Sea Grant Program--which had education as part of its mission. No one will disagree that marine activist Jacques Cousteau had a lot to do with the rise of public interest in the marine world, along with NOVA specials, movies such as Jaws and The Abyss and television programs like Voyage to the Bottom of the Sea, Flipper, and Sea Quest. With this interest, along came the hungry audience for marine education. Today, TV personalities like Bob Ballard, who is famous for exploring the ruins of the Titanic and the Luistania on the ocean floor using submersibles, are continuing to generate large-scale public interest. People now view the world quite differently than they did 40 years ago. Space photos of the earth, global change, and shrinking global resources have stimulated people to look at what the biosphere is made of and their relationship with it. Here is where the future of marine education lies. Perhaps with their pedagogical roots in mind, marine laboratories could assume a greater leadership role in developing scientifically literate citizens.

Currently there are several publications about the Gulf Coast region available that serve as educational resources: *The Gulf of Mexico: A Special Place* (Maraniss, 1991), which is a learning activity book for elementary age school children and *Environmental Quality in the Gulf of Mexico: A Citizen's Guide* (Wber, Townsend, & Bierce, 1990), which is a guide written for the general populace. The Mississippi-Alabama Sea Grant Consortium produced the *Man and the Gulf of Mexico Series* (Irby, McEwen, Brown, & Meek, 1984) in four parts: *Marine and Estuarine Ecology*, *Marine Habitats*, *Diversity of Marine Animals*, and *Diversity of Marine Plants*. All of these publications have significant strengths and limitations. The conclusion is: There is a special need, however, for a secondary school level publication that addresses the Gulf marine environment with appropriate, supportive teaching materials and learning strategies. In addition, the new Gulf Literacy concept focuses and prioritizes the material presented in a way that the preceding books do not. The overt emphasis on meaningful learning and visualization is unique to this research project.

Meaningful Learning

Ausubel, Novak, and Hanesian (1978) provided a useful volume on educational psychology with emphasis on meaningful learning and the importance of prior knowledge. Meaningful learning is further explained by Novak and Gowin (1984). Ausubel et al. (1978) characterize the process of meaningful learning as learning which relates new knowledge to existing relevant concepts in the learner's cognitive structure. This is contrasted with rote learning, in which new concepts are not linked to existing relevant concepts but stored in isolation. Thus a key to the

meaningful learning of concepts is prior knowledge. Ausubel's dictum is well known among science educators:

If I had to reduce all of educational psychology to just one principle. I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him [sic] accordingly. (Ausubel, Novak, & Hanesian, 1978, p. iv)

According to Novak (1980) and Osborne and Wittrock (1983), learning involves sensory perception, attenuation, short-term memory, active rehearsal, long-term memory and recall. New concepts acquired in this manner interact with stored memory during the construction of meaning. These meaningful connections join concepts to form a conceptual framework which provides an understanding of the world from the individual's point of view (Gilbert, Osborne, & Fensham, 1982).

Consistent with this are constructivist views that knowledge is synthesized, modified, and evolving. This requires the active participation of the learner as new experiences are interpreted in the light of previous experiences. Learning is an active process that requires students to retrieve knowledge from long term memory; apply information processing skills in generating meanings from sensory data; and organize, code, and make meanings available in long-term memory (Driver & Bell, 1986; Osborne & Wittrock, 1983; Pope & Gilbert, 1983).

The generative learning model of Osborne and Wittrock (1985) states that meaningful learning begins, not with experience itself, but with selected attention to specific relevant aspects of experience. Selective attention, in turn, dictates perception and is itself dependent upon the store of images, episodes, propositions, and skills already possessed by the learner.

Conceptual Change

A useful model of conceptual change was proposed by Posner, Strike, Hewson, and Gertzog (1982). This model was developed under the influence of 20th century philosophers such as Brown (1977), Toulmin (1972), Kuhn (1970), and Lakatos (1970). The essence of the model is based upon the principles of assimilation and accommodation. When students use existing concepts to understand new phenomena this is called assimilation. When a student's currently held concepts are inadequate to allow the successful grasp of new phenomena, then the student must replace or reorganize his/her central concepts. This more radical form of conceptual change is called accommodation. Consistent with other learning theories, Posner's group holds that learning occurs against the background of the learner's current concepts. These currently held concepts are necessary for the learner to ask questions and make sense of any new phenomena. Toulmin (1972) referred to these concepts that govern conceptual change as a conceptual ecology.

Posner's theory of accommodation is expressed in response to two questions: (a) Under what conditions does one central concept become replaced by another? and (b) What are the features of a conceptual ecology?

In response to the first question, there are four conditions for an accommodation:

1. There must be dissatisfaction with existing conceptions.
2. A new conception must be minimally understood.
3. A new conception must appear initially plausible.
4. A new conception should have the potential to be extended or open up new areas of inquiry.

An individual's current cognitive resources or conceptual ecology will influence the selection of a new conception. The following kinds of resources are particularly important determinants of the direction of accommodation: (a) anomalies (failures of a given idea) are important; (b) analogies and metaphors; (c) exemplars and prototype images; (d) past experience; (e) epistemological commitments, such as explanatory ideals and general views about knowledge; (f) metaphysical concepts about science; and (g) related knowledge from other fields and competing conceptions.

Conceptual Change in Childhood (Carey, 1985) provides an excellent volume on conceptual change. Carey studied 4-, 6-, and 10-year-old children's understanding of several biological domains. She concluded that there is a strong restructuring of knowledge between the ages of 7 and 10, and that this restructuring parallels major conceptual revolutions in the history of science. A volume of works edited by West and Pines (1985) deals with attempts to elucidate cognitive structure and secondarily on describing ways of changing cognitive structure. Hasweh (1986) suggests that the conceptual change theory can be improved if researchers would specify external factors not previously considered.

Hashweh (1988) also calls for differentiating among three kinds of studies of students' alternative conceptions in science. These are descriptive studies, explanatory studies, and studies attempting to foster conceptual change. He reviews descriptive studies in an attempt to illustrate the need for such differentiation and methodological considerations. In a separate paper by Hasweh (1986), a review of explanatory studies is given. Lee and Anderson (1993) add that there is a need to integrate learning/cognition with motivation/affect in conceptual

change research. Demastes (1994) conducted a study of conceptual change in high school students relative to their understanding of evolution. Her findings from a multi-case study of conceptual change include:

1. Conceptual change about evolution of life can occur in one of three patterns: (a) holistic, (b) fragmented and gradual, and (c) dual constructions.
2. Conceptual change can occur with little corresponding change in belief.
3. The most influential factor inhibiting conceptual change toward a more scientific framework is not belief, but the learner's feeling of disturbance and conflicts as learning occurs.
4. Conceptual change is often based upon the idiosyncratic, extra-logical assessment of competing conceptions.

Research methods of conceptual change research emphasize qualitative methods (Gunstone, White, & Fensham, 1988; Lythcott & Duschl, 1990). Interviews and think-aloud protocols provide rich sources of information which can create certain problems in data reduction and valid interpretation. Guidelines for gathering informal verbal data and for data reduction have been reported by Ericsson and Simon (1987), Novak and Gowin (1984), Osborne and Freyberg (1985), (1984), Piaget (1929), Pines, Novak, Posner, and Kirk (1978), Powney and Watts (1987), Toulmin (1969), White (1985), and White and Gunstone, (1992).

Graphics

A graphic metacognitive tool, the concept map, is the product of Novak and his colleagues at Cornell (Novak & Gowin, 1984). It is a more familiar tool, resulting from almost 20 years of research and development. Concept maps are also based upon Ausubelian learning theory. Mappers

must hierarchically order concepts and connect concepts with each other including the linking words for those connections, and thus revealing salient aspects of their cognitive structure. This allows for evaluation of prior knowledge and diagnosis of misconceptions. The concept map serves as a device to illustrate the hierarchical, conceptual, and propositional nature of knowledge. It also serves as a metacognitive tool to help learners reorganize their cognitive frameworks into more powerful integrated patterns. Using the metaphor extended by Wandersee (1990) in his comparison of knowledge construction and cartography, "to map is to know."

In addition, as a metacognitive tool, concept mapping promotes meaningful learning. Carey (1986) recommended the comparing of successive concept maps in determining knowledge acquisition. Concept maps were also used to explore conceptual change in college biology classes by Wallace and Mintzes (1990). They found that maps are a useful mechanism to look at changes in cognitive structure. The use of concept mapping in a college course on evolution was explored by Trowbridge and Wandersee (1994) in the first phase of this study. Key findings included: (a) that critical junctures in learning evolution can be identified by monitoring the degree of concordance of the superordinate concepts appearing on the class set of concept maps submitted after each course lecture, (b) students who made concept maps reported spending an average of 37% more study time on this map-based college biology course than their previous biology courses, and (c) the use of "seed concepts," "micromapping," a standard format, and a standard concept map checklist made the strategy feasible for the instructor to implement and for the student to adopt. The *Journal of Research in Science Teaching* devoted a

special issue on perspectives in concept mapping (Novak & Wandersee, 1990).

Another graphic metacognitive tool is Gowin's epistemological vee. The vee is helpful in the construction of new knowledge and in understanding its construction. The vee relates methodological elements with concepts, principles, theories, and philosophies. A person's existing concepts (prior knowledge) and even her/his world view affect the methods used in research and knowledge making. This tool helps students visualize the interacting elements of knowledge production. The vee has been especially useful in laboratory work and research analysis (e.g., prospectus defenses and proposals).

Other graphics allow the visualization of scientific data. To provide a review and coherent theory of graphics, Tufte (1983, 1990) has written two volumes: *The Visual Display of Quantitative Information* and *Envisioning Information*. These informative books help readers to understand that the construction of a high quality informative graphic is a science where many visual as well as learning principles are involved.

Interviewing

In current science education research, the qualitative method used most often for gathering data about childrens' knowledge is the clinical interview (Lythcott & Duschl, 1990). The interview, as a research tool, provides a way of finding out how children describe and explain the world around them. The approach permits the investigator to use a fairly structured set of questions and probes which attempt to uncover conceptions held by the subject (Erickson, 1981). The clinical interview, when properly conducted, provides a penetrating assessment of a student's knowledge (Novak & Gowin, 1984). The method, a variant of the

Socratic method of dialogue (not Socratic teaching) and Freudian analysis, was pioneered by Piaget and used in his investigations about the nature and extent of children's knowledge of the world (Piaget, 1929). Current techniques modify the method to explore children's views of specific science concepts and explanations of events (Gunstone et al., 1988; Hasweh, 1988; Osborne & Freyberg, 1985; Posner & Gertzog, 1982). The interview allows for probing, clarification, and follow-up of responses. Answers that seem vague or somewhat incomplete can be further explored. Sources of linguistic confusion can also be studied. The method has the flexibility to adapt to a wide range of researcher needs. Some studies distinguish between a clinical interview used to gather verbal data and a clinical interview used in a task situation. Many research programs actually combine both techniques.

It must be realized that the interview method is both time consuming and labor intensive. There are biases that must be avoided in the interview technique. First, the authoritative nature of the interviewer and his/her ability to elicit responses. The misrepresentation of responses by the researcher is another area of concern. Second, the interviewer must let the responses be the subject's and not suggest or prompt a response. Third, the interviewer must not hold a predetermined hypothesis about what a child knows and attempt to guide the general flow of the interview in that direction. Fourth and, the interviewer must be careful about affirmations or rejections, head nodding, and "un huhs." Procedural recommendations have been developed by Pines (1978), Osborne and Freyberg (1985), Lythcott and Duschl (1990), and Powney and Watts (1987). Along with some of the above considerations, some specific principles of clinical interviewing are noteworthy:

1. An interviewer should continually reiterate his/her stated interest in the student's meaning, and not go looking for an answer which can be assessed with respect to some external criterion.
2. Follow-up questions are particularly crucial, but must not lead the respondent.
3. The interviewer should explore the reasons behind a student's initial answer; if a student's answer is difficult to understand, the interviewer should try to get at just what the student is trying to say.
4. Doubt and hesitation expressed by the student should be explored.
5. Interviewers need to be sensitive to students' contradictory responses.

Novak and Gowin (1984) discuss logistics problems, as well as a number of other problems and issues:

- (1) Interviewing should not be Socratic teaching.
- (2) Interviewers must be thoroughly familiar with the material to be covered.
- (3) Personality factors are important.
- (4) Interviewers must listen to the students they are interviewing.
- (5) Patience is required.
- (6) The interview atmosphere should be relaxed and calm.
- (7) Irrelevant discussion should be discouraged.
- (8) "I don't know." or "I forgot." answers seldom mean just that.
- (9) Students vary widely in loquaciousness.
- (10) Statements revealing feelings are often significant.
- (11) In sequential interviews, it can be helpful to refer to prior interviews and/or to relevant intervening instruction.

(12) The student's own language should be used to rephrase questions or to probe further.

(13) The interviewer's logic should not be forced upon the student.

(14) Interviews should end on a positive note.

Interviews generate voluminous data and a reduction of sorts must take place. After analyzing a number of interview tapes, a series of categories will emerge and allow grouping of responses. (There may still be a large number of responses that are unique and important.) Categories may also be constructed by an independent researcher to establish the validity of data reduction techniques.

Lythcott and Duschl (1990) use warrants to draw conclusions from data in a defensible fashion after Toulmin (1969). One such warrant is novel verbiage used by the subject. Words or meanings not introduced must be part of the subject's cognitive structure. A second warrant is that words with scientific meanings may only have meanings ascribed to them that are given in conversation by the subject, whether introduced by the interviewer or the subject; common meanings, scientific or otherwise, may not be inferred. For example, the concept animal was introduced in interviews done by Trowbridge and Mintzes (1988) and was subsequently used by subjects, but that does not mean the subjects held a scientifically acceptable idea of the concept animal. The verbiage was not novel, but usage was restricted so the meaning was novel. Other warrants may manifest themselves and function in the establishment of defensible knowledge claims. Independent researchers can be asked to validate warrants generated. Novak and Gowin (1984) supply a continuum of the types of knowledge claims that can be made from an interview (see Figure 2).

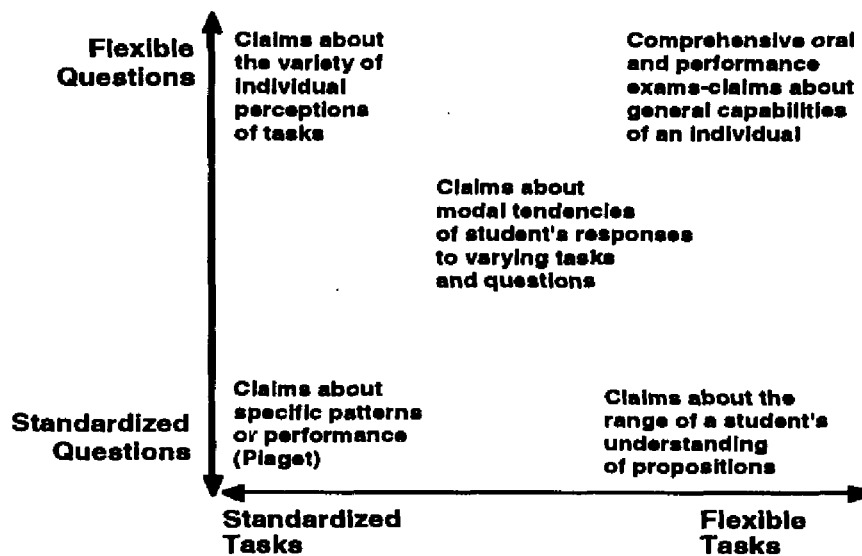


Figure 2. Types of knowledge claims that can be made from interviews (adapted from Novak & Gowin, 1984).

Bogdan and Biklen (1992) report that during the last few years, there has been discussion of a possible code of ethics for qualitative researchers. The notion of informed consent and protection seem little more than a ritual. They lay out some general ethical principles:

1. The subjects' identities should be protected so that the information the researcher collects does not embarrass or in other ways harm them. Anonymity should extend not only to the writing, but also to the verbal reporting of information that the researcher has learned through observation. The researcher should not relate specific information about individuals to others and should be particularly watchful in sharing information with people at the research site who could choose to use the information in political or personal ways.
2. Treat subjects with respect and seek their cooperation in the research. While some advocate covert research, there is a general consensus that under most circumstances the subject should be told of one's research interests and should grant permission to proceed. Researchers should neither lie to subjects nor record conversations on hidden mechanical devices.

3. In negotiating permission to do a study, make clear to those with whom you negotiate what the terms of the agreement are, and you should abide by that contract. If you agree to do something in return for permission, you should follow through and do it. If you agree not to publish what you find, you should not. Because researchers take their promises seriously, be careful as a researcher to be realistic in such negotiations.
4. Tell the truth when you report your findings. Although, for ideological reasons, you may not like the conclusions you reach, and although others may put pressure on you to show certain results that your data do not reveal, the most important trademark of a researcher should be his or her devotion to reporting what the data reveal. Fabricating data or distorting data is the ultimate sin of a scientist. (p. 54)

The researcher must be sensitive and self-reflective to avoid conflicts of race, gender, status, age, or other aspects of equity during the interview process. The researcher should not act superior to the participant.

Furthermore, the researcher is not there as a therapist. Many times the setting, questions, and procedures of the interview give the illusion of psychotherapy. Seidman (1991) recommends going through the process oneself to give the researcher some empathy for the participants.

METHODS

Overview

The research proceeded in distinct phases: (a) development of the Gulf literacy booklet through content analysis of coastal newspapers and expert interviews; (b) instructional use of the booklet in high school classrooms (treatment); and (c) testing the developed model of Gulf literacy through interviews, concept maps, and questionnaires. A flow diagram (Figure 3) is included to illustrate the stages of this research study.

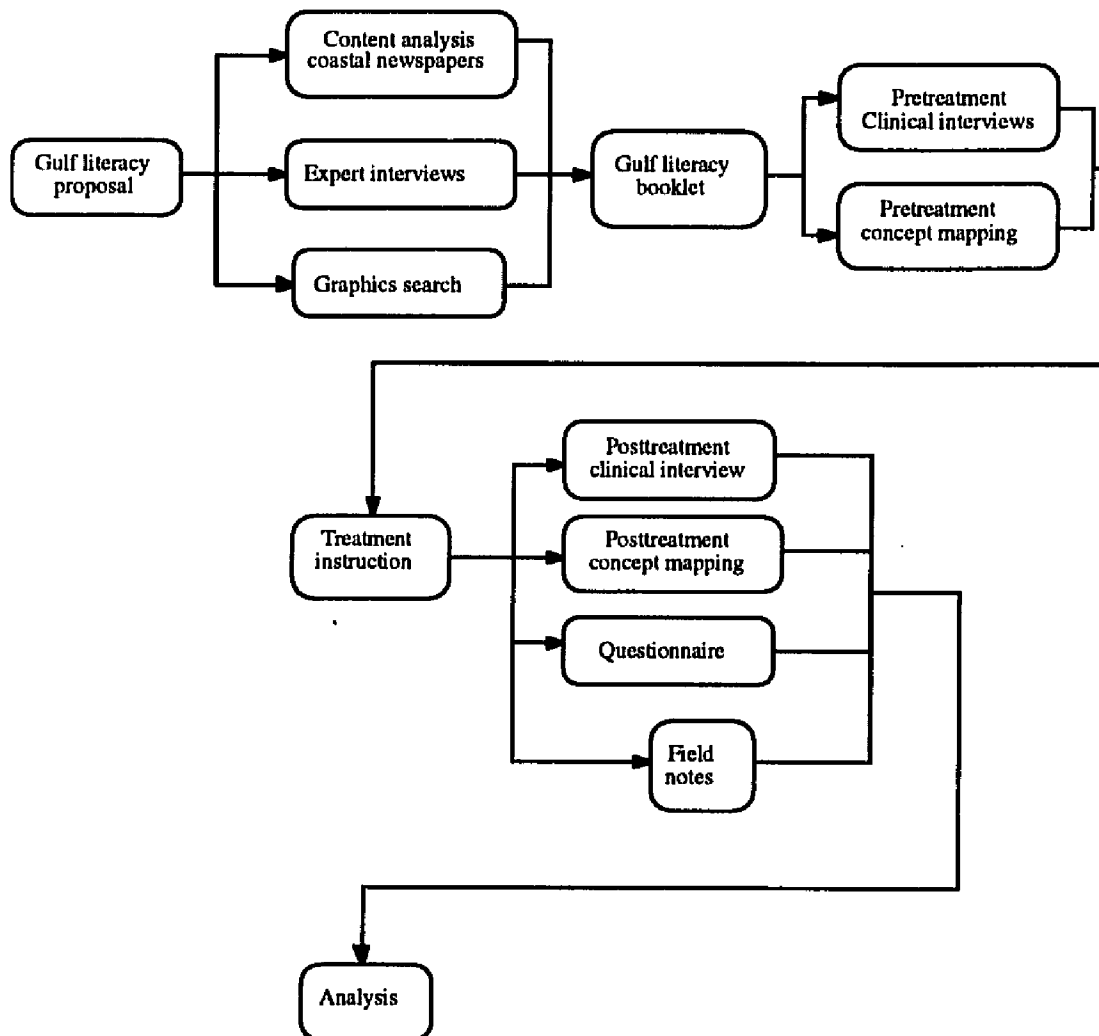


Figure 3. Flow diagram of research.

Gulf Literacy Booklet Development

The first phase of this research program was the development of a Gulf literacy booklet (see Appendix B) to be used for instructional purposes. The booklet's content was developed through (a) the systematic identification of a small number of powerful scientific principles, (b) identification and/or generation of optimal graphics and compelling examples that illustrate and teach these principles, along with actual teaching techniques and learning strategies. The graphics were constructed in a format to serve as an instant overhead teaching transparency master. The goal was to create an 8 1/2" x 11" booklet suitable for a five-day teaching unit on the Gulf of Mexico (later changed to a ten-day unit at the teachers' requests), with graphics flanking each page of explanatory text, and with actual newspaper excerpts from Gulf coast cities. Teachers were educated on the use of the booklet with accompanying activities.

Survey Coastal Newspapers' Archives

A survey of newspapers in major U.S. coastal cities that border the Gulf of Mexico was conducted to determine a catalogue of scientific and environmental issues concerning the Gulf of Mexico. Newspapers were chosen as a source of data/information because, in several of the definitions of scientific literacy, the ability to read and understand newspaper articles and graphics about scientific issues was a key component (AAAS, 1990; Demastes & Wandersee, 1992; Hazen & Trefil, 1990).

The term "content analysis" can be defined as "analysis of the manifest and latent content of a body of communicated material . . . through a classification, tabulation, and evaluation of its key symbols and

themes in order to ascertain its meaning and probable effect" (*Webster's Ninth* , 1983). It is especially useful in making replaceable and valid inferences from complex, voluminous data to their content, to describe trends in communication content and to reveal foci of attention (Krippendorff, 1980, pp. 21, 31; Wandersee, 1990; Wandersee, Mintzes, & Arnaudin, 1989).

Archive data bases (computer, print volumes, vertical files, or microfiche) covering the last five years (1989-1993) for the *Tampa Tribune* in Tampa, *Mobile Register* in Mobile, *Times Picayune* in New Orleans, and *Corpus Caller* in Corpus Christi were selected for analysis. A five-year period was chosen because beyond that time span issues and events would not be meaningful to the students (high school) taking part in the study. Descriptors for the searches included Gulf of Mexico, fisheries, shrimp, red fish, by-catch, oysters, overfishing, reefs, water quality, pollution, sedimentation, red tide, endangered species, sea turtles, marine debris, toxic waste, erosion, and marine mammals.

Search for Graphics

As part of the aforementioned search of coastal newspapers, a catalog of graphics and their sources was compiled. Many of these graphics were incorporated (with permission) into the instructional booklet. Further sources of graphics that were searched included Gulf region scientists, Gulf region marine laboratories, Stennis Space Center, the Gulf of Mexico Program, Minerals Management Service, Louisiana Energy & Resource and Information Center, journals, and books. Some graphics were created using computer graphic programs or drawn by the author.

Interview of Key Marine Scientists and Marine Educators

A marine scientist and marine educator from the eastern, central, and western portions of the U.S. Gulf were interviewed to reveal their ideas about major Gulf issues and what their vision of Gulf literacy would entail ($N=6$). While the newspaper searches generated data on the popular or public level, the interviews of experts added an additional layer of data and increased the validity of the resulting model.

The resulting booklet was reviewed by two high school teachers, four university professors of science education (three were former school teachers), a marine educator, and a marine scientist.

Treatment

Subjects

The student research component involved students ($N=94$) from four high school environmental science classes in southern Louisiana, each taught by a master teacher. The students are juniors and seniors. Two magnet schools from Baton Rouge were chosen. The student population at one of these schools (suburban) is 90% Afro-American and 10% white. The other Baton Rouge school is 60% Afro-American, 30% white, and 10% Asian (urban). A rural high school from Livingston Parish was chosen. This school is 99% white. The fourth school located in Hammond, Louisiana, a small town, has an 80% Afro-American student population, the remaining 20% is white. Each student completed a posttreatment questionnaire. For clinical interviews and coconstruction of concept maps, six students from each class were selected ($n=24$). A purposive sample of six students in each class was used. They were selected to represent a range of ability levels (high, average, low) as

determined by the teacher and previous science grades. Both genders (male and female) were equally represented as well.

Teacher Preparation

It was essential to the success of this study that the participating teachers were fully briefed about the research as well as be instructed on the use of the graphics booklet. The participating teachers received approximately six hours of conferencing with the researcher covering: (a) necessary background on the Gulf of Mexico, (b) history of the research project, (c) development of the graphics booklet, (d) specific activities and lessons, (e) selection of students to interview, and (f) administration of the questionnaire.

Pretreatment Coconstruction of Concept Maps

A first time attempt at pretreatment coconstruction of concept maps was unsuccessful and dropped from the program. The pretreatment interview was relatively lengthy and students were unfamiliar with the terms and concepts as well as the process. They became frustrated. Thus, for the sake of the student-researcher relationship, the concept mapping was reserved for a posttreatment exercise only. This was decided after three attempts.

Pretreatment Clinical Interview

To assess students' baseline knowledge of selected concepts related to Gulf literacy, interviews with a subsample of 24 students were conducted. The subsample consisted of a male and female from high-, average-, and low-ability groups within each of the four participating classes. An interview protocol was developed based upon content of the Gulf literacy booklet. Two teachers and two university educators were asked to examine the protocol for content validity, language, and level of

questions appropriate for high school students. Below is the resultant protocol after corrections and suggestions.

Interview Protocol

1. Describe the Gulf of Mexico: (show map of Gulf without detail)
 - . . . its boundaries and comparative size
 - . . . its depth
 - . . . its characteristic features (any unique features?)
 - . . . the currents
 - . . . its rivers
 - . . . estuaries
2. What have you recently heard, seen or read about the Gulf of Mexico?
3. Do you think there are any environmental problems related to the Gulf of Mexico?
4. Is there anything you are personally concerned about regarding the Gulf of Mexico?
5. What does the term salinity mean and why is it important in understanding the Gulf LME?
6. What are important fishery resources of the Gulf?
 - tell me about oysters
 - tell me about shrimp
 - tell me about nursery areas
7. Tell me about storms.
8. Show example of marine debris- ask about.
9. What do rivers bring to the Gulf?
10. Can you explain dead zones?
 - anything about phytoplankton?

. . . . anything else about nutrients?

. . . do you know their sources?

11. Are you going to do anything about staying informed about the Gulf?

. . . . through newspapers

. . . . a club

12. Do you have any personal connection to the Gulf? What is your affect on the Gulf?

13. Students were presented with pictures from C.C Lockwood's (1984) book The Gulf Coast (p. 22 manatees, pp 36 & 37 shrimping, p. 40 marsh, p. 51 marsh, p. 67 dunes, p. 103 developed barrier island, and pp. 118 & 119 tern nesting colony).

Interviews were audio recorded and transcribed for later analysis.

Posttreatment Clinical Interviews

A posttreatment interview was conducted to determine the level of Gulf literacy achieved by the students. Additional questions were asked about (a) how students would seek additional information on the Gulf of Mexico; (b) their perceived role in Gulf management; and (c) important anticipated needs or issues related to the Gulf of Mexico.

The participating teachers were also interviewed to gain information relative to their experience from teaching the unit and use of the graphics booklet.

Concept Mapping

Concept mapping has multiple uses for the teacher, student, and researcher. It can be used as a study guide and to organize a lesson, prepare a talk, survey a chapter or a text, synthesize class notes, show

prior knowledge of a subject, and give an approximation of a person's cognitive structure related to a concept. This is only a partial list because the utility of this metacognitive tool is constantly growing.

Concept maps are two-dimensional representations of a set of concepts. The concepts are arranged in a hierarchy with a superordinate concept at the top. The concepts are linked by lines with connecting words that form the propositions uniting the concepts. There are cross links connected by dotted lines (by convention) that join branches of the map to create new propositions. A concept map should be anchored with examples, ideally novel, mapper supplied, examples.

Concept maps can give the researcher an idea of how students are organizing their knowledge through their choice of superordinate concepts and its resulting hierarchical organization. This is known as "progressive differentiation." Learning theory shows us that the brain through its sensory and memory systems stores and retrieves knowledge in an organized hierarchical fashion. The linking of the concepts to each other and the creation of cross links is called "integrative reconciliation." Here it can be determined if appropriate linkages have been made using appropriate linking words.

Not only is concept mapping an activity that fosters active engagement in every student, but it is also a "highly sensitive tool for measuring changes in knowledge structure" (Novak & Wandersee, 1990, p. 946). In addition, as a metacognitive tool, it promotes meaningful learning. Concept maps are compatible with meaningful learning theory (Ausubel, Novak, & Hanesian, 1978) because map construction involves organizing concepts, linking existing concepts to other relevant concepts,

arranging these concepts hierarchically, and labeling the linkages between concepts.

Concept mapping seems to fit well with constructivist views that learners construct their own idiosyncratic understanding of concepts and natural phenomena (Gowin, 1981). Constructivism has as its central assumption that the learner is an active participant in the learning process. Thus, it may be concluded that the construction of concept maps has the potential not only to improve students' understanding of science concepts, but also to monitor students' evolving understanding of concepts.

Carey (1986) recommended the comparing of successive concept maps for determining knowledge acquisition. Concept maps were also used by Wallace and Mintzes (1990) to explore conceptual change in college biology classes. They found that maps are a useful tool for examining changes in cognitive structure. Novak and Musonda (1991) performed a 12-year longitudinal study that demonstrated that concept maps can be used effectively in analyzing conceptual change, even across large time intervals. Novak and Musonda generated the concept maps in their study from student interviews.

A set of Gulf science concept maps developed by the author served as a guiding referent in the development of the graphics booklet and the model of Gulf literacy (see Appendix C).

Posttreatment Coconstruction of Concept Maps

Along with the posttreatment interview, a set of concept maps was constructed from the context of "Human Impacts." The student was supplied this concept as the superordinate concept and asked to generate a list or bank of related concepts. The researcher wrote these terms on Post-it Notes TM and set them aside. The student then placed the terms on

a white board and rearranged as necessary. Once the map was drawn the student reinspected and made changes if he/she wished. Using the marker board allowed for changes and restructuring with minimal delay (Wandersee & Abrams, 1993). Each completed map was photographed using instant photography, insuring a usable copy for later analysis.

Posttreatment Questionnaire

All students completed the posttreatment questionnaire on Gulf literacy components. This large-scale posttreatment questionnaire also used Likert-type scale items (see Appendix D). The study's review panel was asked to evaluate the questionnaire for content validity and appropriate reading level. Descriptive statistics summarized questionnaire results.

RESULTS

Model Development

The development of the Gulf literacy model was facilitated by a content analysis of Gulf Coast newspapers and expert interviews. The resulting conceptual model was the basis for developing a teachers guide to Gulf literacy (see Appendix C). This instructional guide was used by teachers as the basis of a two week unit on the Gulf of Mexico (treatment).

Content Analysis of Coastal Papers

Corpus Christi Caller

Corpus Christi, Texas is a minor city of approximately 257,000 people (World Almanac, 1994). Its location represents the western side of the U.S. Gulf of Mexico. The newspaper search was conducted in the public library's historical collection vertical file. A total of 63 articles were found within the available files for the period of November 1988 to November 1994. There was no available index for this newspaper. Therefore, articles were preselected by librarians prior to researching the files. Articles were grouped according to seven major categories (see Figure 4). The top three concerns as reported by the *Corpus Christi Caller* were oil & gas related (27%), fishery topics (25%), and pollution (23%).

Times Picayune

New Orleans, Louisiana is a major city with an estimated population of 1,000,000 within the metropolitan area. Actual population within the city limits is approximately 500,000 (World Almanac, 1994). This location represents a central perspective of the Gulf of Mexico. The *Times Picayune* was indexed by the *Times Picayune Index* (University

Microfilms International, 1988-1994). The library at Southeastern Louisiana University held all articles found. A total of 241 articles were found in the *Times Picayune Index* for the period of November 1988 to November 1994. As seen in Figure 5 articles on fisheries (24%) and storms (21%) dominated the *Times Picayune*.

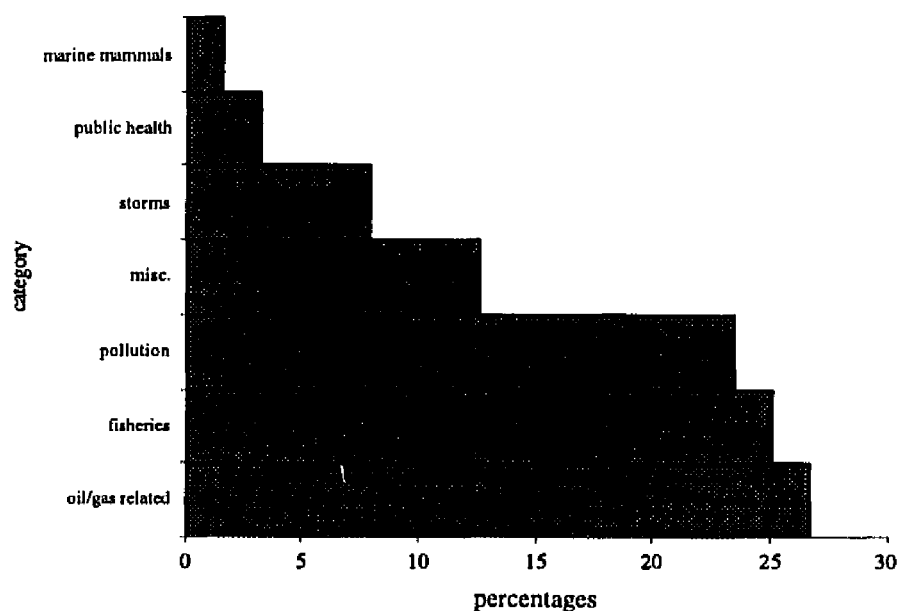


Figure 4. Corpus Christi articles in rank order as percentages ($n=63$).

Note: Category miscellaneous includes topics such as fault lines, zebra mussels and radioactive pits.

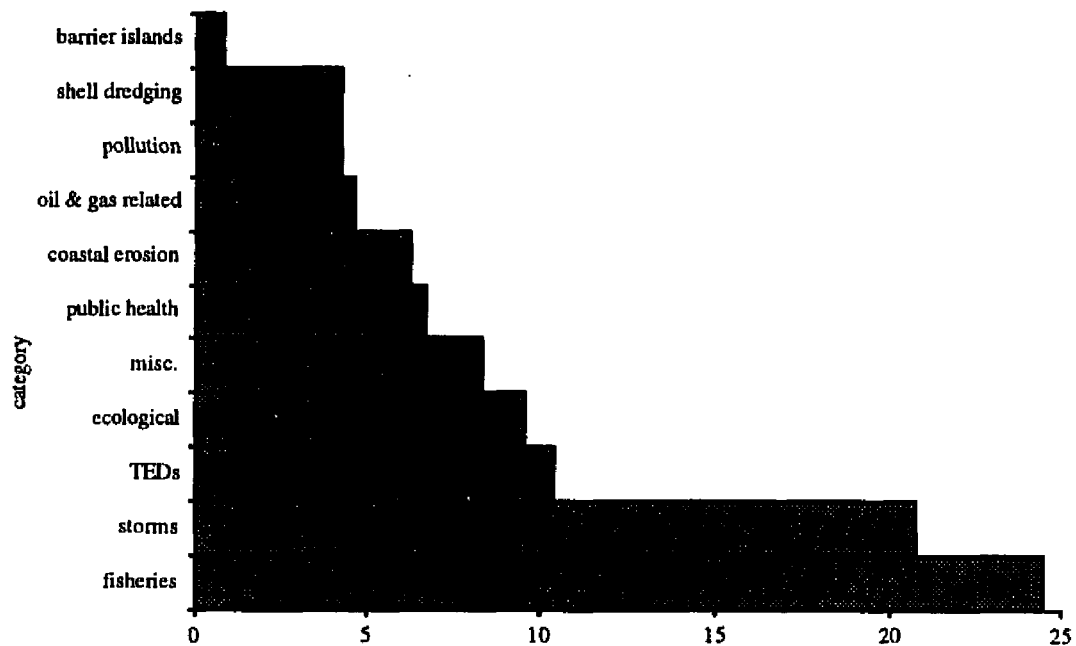


Figure 5. New Orleans articles in rank order as percentages ($n=191$).

Note: Category miscellaneous includes topics such as piranhas, fresh water diversion, and Mississippi River Gulf Outlet.

Mobile Register

Mobile, Alabama is a minor city of approximately 200,000 people (World Almanac, 1994). Its location represents the eastern-central Gulf of Mexico. Similar to Corpus Christi there was no index to the *Mobile Register*. The vertical file in the historical collection of the Mobile Public Library was the data source. A total of 69 articles were found in the historical collection's vertical file for the period of November 1988 to November 1995. Fisheries (42%) and pollution (36%) concerns dominated the articles retrieved (see Figure 6).

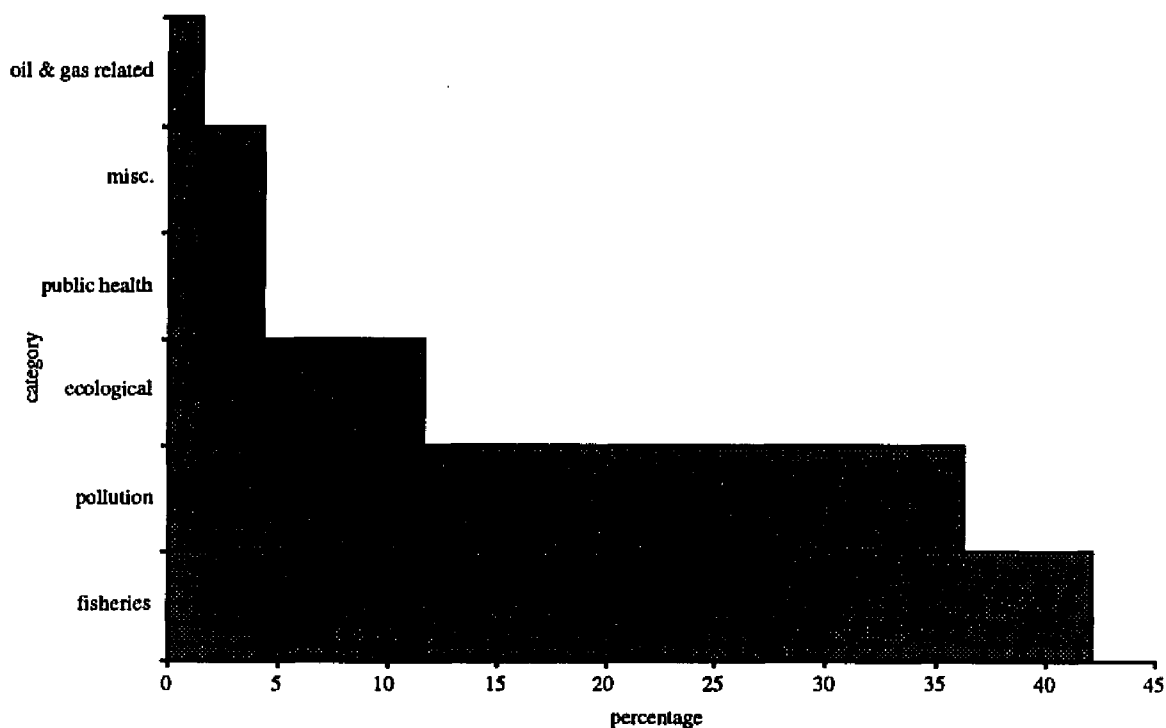


Figure 6. Mobile articles in rank order as percentages ($n=69$).

Note: Category miscellaneous includes topics such as Sierra Club, politics, and research.

Tampa Tribune

The Tampa metropolitan area has an approximate population of one million (World Almanac, 1994). This includes St. Petersburg and surrounding counties with high population density. This location represents the eastern Gulf of Mexico. Full-text searching capability was available at the University of South Florida for approximately four of the five years searched (November 1989 to November 1994). The other year (November 1988 to November 1989) was searched through the Tampa public library. Although there was a wide range of miscellaneous issues, a large percentage of the articles focused on fisheries (18%), ecological

issues (16%), oil and gas (11%), and marine mammals (11%) (see Figure 7).

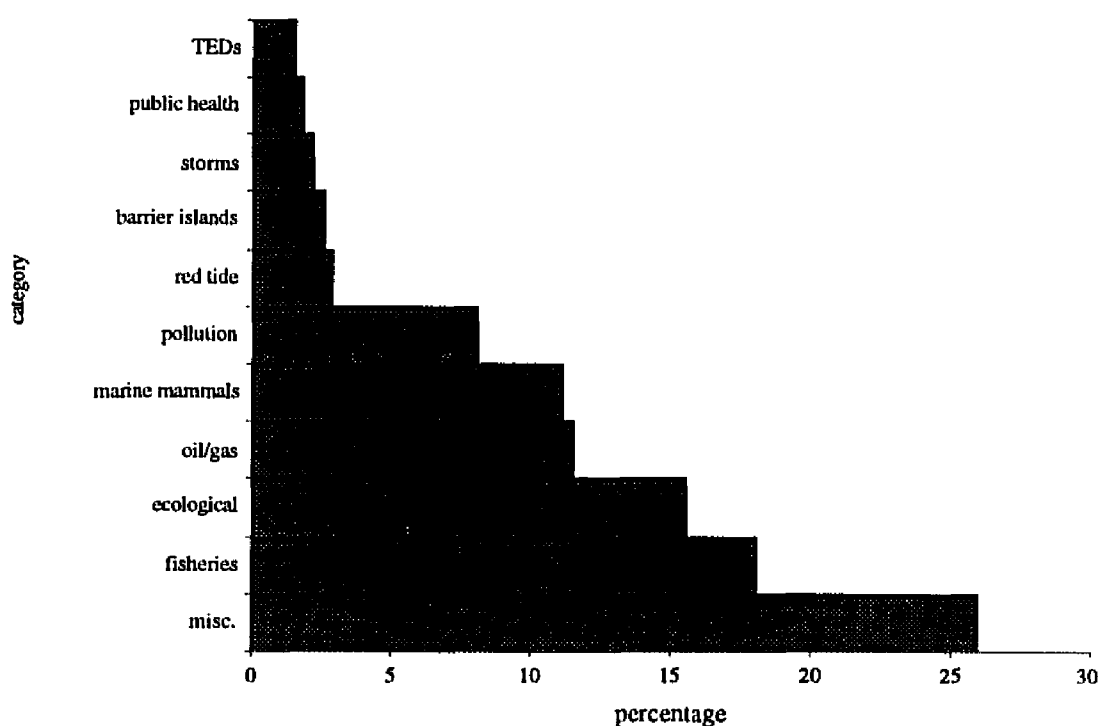


Figure 7. Tampa articles in rank order as percentages ($n=290$).

Note: Category miscellaneous includes topics such as U.S. Navy, desalination of seawater, and Gulf of Mexico Program.

All Cities

When content analysis data for the four cities were combined, fisheries issues out ranked most others. There was a great deal of variability between issues from location to location. There seem to be some strong oil and gas concerns in Corpus Christi and strong pollution

concerns in Mobile and Corpus Christi as compared with other locations (see Figure 8).

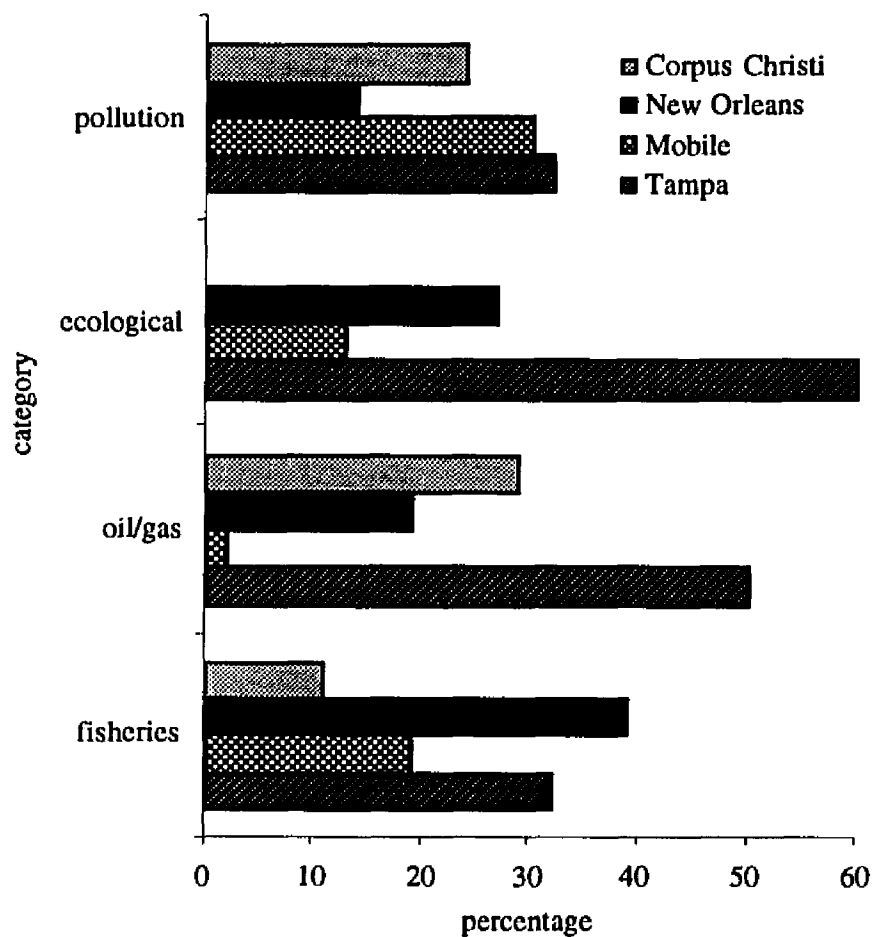


Figure 8. Comparison of the four cities on top issues.

Note: Ecological issues for Corpus Christi equals 0%.

Expert Interviews

Interviews with three marine educators and three marine scientists initially revealed 73 major concerns, issues, or concepts they felt a student leaving high school should know in order to be Gulf literate. These concerns, issues, or concepts were collapsed into 32 major concepts (see Table 1). For instance commercial fishing, shrimp, and oysters were all grouped under the concept of fisheries. These concepts along with major issues reported in the newspapers were the basis for the concept map model and booklet development.

Table 1
Summary List of Major Concepts Derived from Experts

<u>Major concepts</u>	
bay systems	Mississippi River
biodiversity	nonpoint source pollution
bordering states	nutrients
channelization	oil & natural gas
currents	physiography
dead zones	population
debris	recourses
eco-communities	red tide
erosion	reefs
estuary	rivers
fisheries	salt domes
freshwater	sea grass beds
funding	shellfish poisoning
habitat	stewardship
history	water quality
manatees	wetlands

Experts supplemented the issues and concepts reported in the newspapers. For instance, in the content analysis of the newspapers, the topic of salt domes was not mentioned. However, two experts mentioned

them as a unique feature of the Gulf of Mexico. Therefore, salt domes were included in the model. One educator and one marine scientist used newspaper articles in their teaching and presentations. Five of the six were cautious of newspapers because of sensationalism, bias, and their personal experience in being misquoted. One scientist stated that she prefers to use press releases and has had better results in accuracy of reported information about her work.

This group was asked for good sources of information about the Gulf of Mexico. Three mentioned that the public aquaria system along the Gulf Coast seemed to help the public understand the Gulf and its ecological processes. Other sources mentioned were: (a) Sea Grant agencies, (b) Nova-type TV specials, (c) museums, (d) *Oceans* and *National Geographic*-type magazines, (e) newsletters, and (f) a computer bulletin board called *Gulf Line*.

Booklet as the Treatment

A 76-page instructional booklet was developed based upon the model (see Appendix C). The booklet includes a color cover with a satellite image of sea surface temperatures of the Gulf on the front and a satellite image of Hurricane Andrew in the Gulf on the back cover; a set of concept maps that were the framework for Gulf literacy; and lesson topics under each superordinate concept. Each topic was supported by at least one graphic or visual that can easily be made into an overhead transparency. A set of relevant concepts, at least one newspaper article title related to the topic, background information, and a classroom activity was also provided for each topic. The participating teachers used this booklet to teach a two week unit on the Gulf of Mexico.

Pretreatment Interviews

A clinical interview was conducted with six students from each school for a total of 24 interviews. The interview was structured by a written protocol, but allowed freedom of responses by the students as well as follow up of responses by the researcher.

General Knowledge of the Gulf

Of the students queried ($n=17$), "What do you know in general about the Gulf of Mexico?" the largest number of common responses focused on boundaries, specifically the states that bordered the Gulf (41%). The next largest categories identified from the responses were: (a) existence of an oil industry (24%), (b) its saltwater (24%), (c) the Mississippi River empties into it (24%), and (d) contains fish or supports a seafood industry (24%).

Boundaries

With regard to boundaries of the Gulf, 70% of the students asked ($n=23$) correctly identified the boundaries of the Gulf of Mexico. Incorrect responses included: I don't know ($n=2$) or mention of a non-bordering state, such as Georgia and Hawaii.

Size and Depth of the Gulf

Students' ($n=24$) estimates of the distance from the Mississippi River Delta to the Yucatan Peninsula ranged from 150 to 5,000 miles. Five (21%) of the students were within plus or minus 100 miles of the actual 900 mile distance. One third of the students ($n=8$) stated they had no idea or admitted to a wild guess. For the question, "How many states of Louisiana would fit into the Gulf of Mexico?" answers ranged from 1 to 50 with 3 of the 22 students answering within a plus or minus 2 states range of the actual 13 states would equal the area of the Gulf. Students'

estimates of the deepest part of the Gulf ocean basin were literally shallow. The range of depths given were 100 to 20,000 ft. The "20,000 ft." and a "two miles" responses were the only ones within the tens of thousands of feet scale, there was a "mile" response, and all other responses were less than 1,000 ft. However, 41% indicated they did not know.

Concept Estuary

The concept of an estuary was not familiar to 82% of the students with 14 "no idea" or incorrect responses. Three students had a general idea as indicated by the following responses: "where freshwater and saltwater meet," "mixture of fresh and saltwater," and "where a river empties into the ocean."

Rivers

Responses to what rivers the students knew about centered around the Mississippi River. The Mississippi River was named by 96% (n=22) of the students asked (n=23). Beyond the Mississippi River, five students mentioned an additional river, six students mentioned two additional rivers, and one student mentioned four rivers. In addition three students mentioned lakes that empty into the Gulf. The additional rivers mentioned include: (a) Atchafalaya River, (b) Amite River, (c) Pearl River, (d) Sabine River, (e) Rio Grande, (f) Choctaw River, and (g) Tangiphoa River. The lakes identified were Lake Maurpa, Lake Pontchartrain, and Lake Charles.

Recent Information About the Gulf

Approximately half of the 21 students asked (n=11 or 52%) had not heard, seen, or read anything recently about the Gulf of Mexico from the

normal variety of sources such as radio, television, or newspapers. Six or 29% recalled hearing or seeing something about hurricanes.

Environmental Problems

With regard to students' notions relative to environmental problems, 10 out of 22 (45%) students mentioned coastal erosion or wetland loss. Pollution and oil industry were the next highest categories of responses, both at 27% (n=6).

Personal Connections

Students' responses (n=18) about personal connections to the Gulf were varied. The responses that could be categorized include chemical dumping (22%), seafood industry (17%), and erosion concerns (17%). Some of the varied responses include recreational use, economic connections, and resources.

Commercial Fishing

Out of the 20 students queried about their knowledge of commercial fishing 40% (n=8) mentioned shrimp or shrimping, 30% (n=6) mentioned pollution, and 20% (n=4) recognized an economic connection.

Storms

Students' responses (n=18) as to what they knew about storms related to the Gulf of Mexico indicated an association with hurricanes (94%). Three students mentioned the association with warm water and hurricanes.

Dead Zones

Virtually all the students (n=18) were not familiar with the phenomena of dead zones (94%). Only one student gave a partially acceptable explanation.

Plankton

After summarizing responses (n=19) related to the concept plankton, this researcher noted only three students reported an understanding of plankton. Most of the other responses were vague (e.g., "stuff whales eat," "it's on top of the water," and "that's like fish").

Staying Informed About the Gulf

When students (n=19) were asked, "What do you do to stay informed about the Gulf of Mexico?" most answered they would watch the news (56%), read newspapers (32%), and consult other sources such as journals, magazines, books, or teachers.

Photograph of a Manatee

When presented with a picture of a manatee (n=18), 61% of the students recognized that it was a manatee and 39% (n=7) stated additional information such as "it's endangered" and "harmed by boats."

Photograph of a Shrimp Boat

Out of the 19 students presented with pictures of shrimping, 21% (n=4) mentioned the importance of shrimping as an industry. Other answers were varied such as "shrimp nets are catching turtles," "it's popular down here," and "shrimp live on the bottom."

Photograph of a Salt Marsh

Students' responses (n=18) to the photograph of a salt marsh and the question, "Is this fresh or saltwater?" produced a variety of answers indicating students were unsure of marsh type and had no criteria to judge. Many students (n=5) classified some sort of wetland attribute to it e.g., "part of the delta system," "a bayou swamp," and "looks like marsh to me." However, when presented with a picture of a freshwater marsh

78% identified it as a freshwater system. Several (n=6) cited plants or vegetation as reasons for their answer.

Photographs of a Sand Dune and a Developed Barrier Island

When students (n=19) were presented with a picture of a barrier island (sand dune) and asked to comment, such a wide variety of responses were given such that no real categories of responses could be determined. However, when presented with a picture of a highly developed barrier island, 37% (n=6) had concerns relative to danger from hurricanes and flooding.

Photograph of a Tern Colony

After students were presented a picture of a Gulf-based tern colony, they were asked the question, "Why are these birds here?" Of the 18 students asked, 33% (n=6) mentioned the Gulf as a source of food(fish) for the birds. A variety of other responses included; "its their home" and "they lay their eggs on the beach."

Post Teaching Assessment

Upon completion of the graphics-based unit on the Gulf of Mexico (see Appendix B) all students answered a questionnaire (n=94). Figures 9 - 27 display the most common responses or categorization of responses for each question other than the Likert-type responses that were averaged. Tabular results for each question appear in Appendix E.

Physical Features

With regard to physical features of the Gulf, students listed (a) barrier islands, (b) estuaries, (c) saltwater, (d) salt domes, and (e) rivers as common top responses (see Figure 9). There was considerable variability for the physical features each group focused on. The Urban Magnet High and Rural High students listed barrier islands, estuaries and

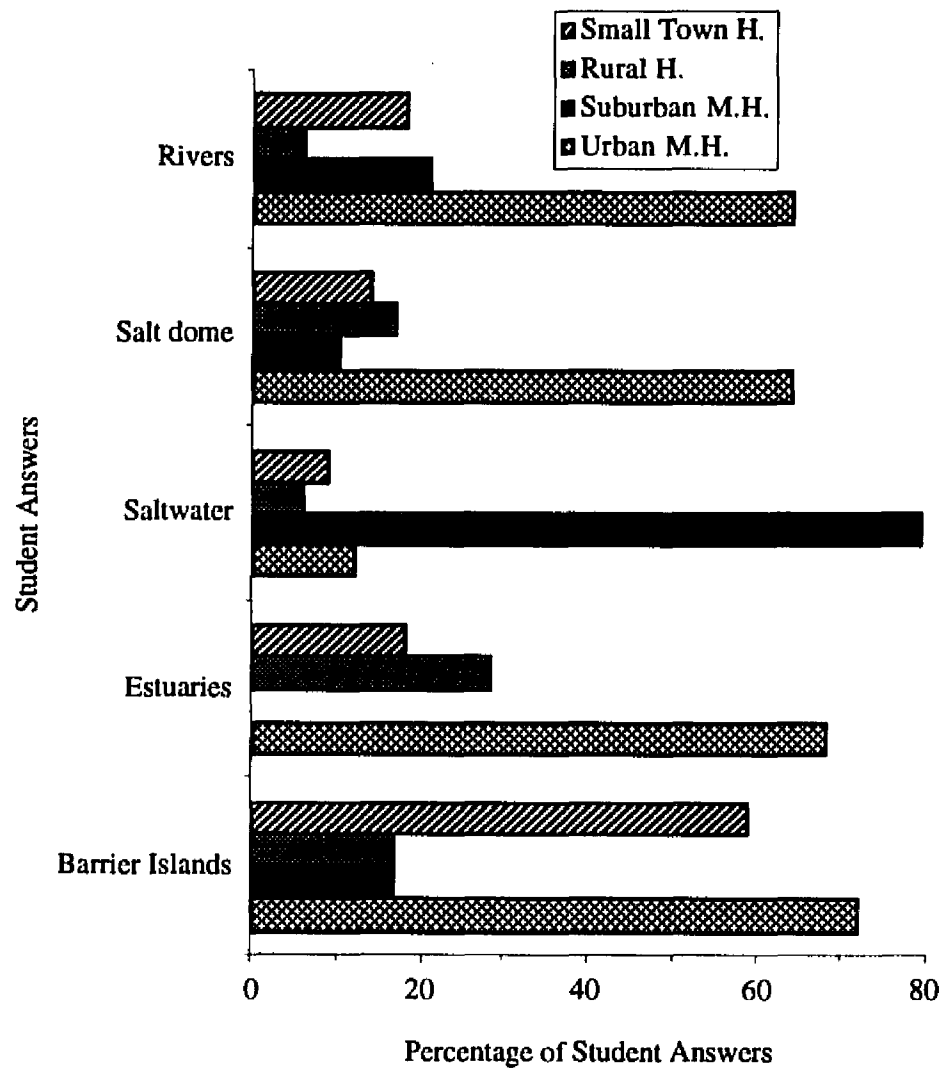


Figure 9. Top five physical features listed by students.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Suburban responses for Estuaries equals 0%.

salt domes as top responses. Whereas, the Suburban Magnet High group focused on shape, size, saltwater, and depth. Saltwater, as a feature of the Gulf, was common to all four schools as a top response. Such variability suggests different teaching approaches and emphasis by the teacher.

Dead Zones

For dead zones, only 9% of all students were able to describe the phenomena with a reasonable degree of accuracy (see Figure 10). An additional 30% were able to indicate there is a lack of oxygen associated with the phenomena and provide some emergent understanding. Since initial understanding of the phenomena was poor to begin with, this represents substantial gains in understanding. One problem may be the metaphorical term associated with the phenomenon, "dead zones." Many answers reflected the idea of an "elephant grave yard" of the ocean where organisms go to die. While the popular press also uses the term dead zone, hypoxia, the more appropriate term, needs to be recognized.

Sources of Nutrients

Responses listing sources of land based nutrients were varied from group to group with all groups demonstrating a clear lack of understanding (see Figure 11). The notion that rivers are the source of nutrients instead of the delivery system further substantiates that this processes is not understood. While it is true that erosional effects of rivers may be a source of terrigenous (land based) nutrients, major sources such as agricultural practices, sewage effluent, and petro-chemical plant effluents were not mentioned. "plants" were listed by 9% of all students. It may not be clear if they mean chemical plants or botanical plants. It may be inferred from the interview data they are referring to petro-chemical type

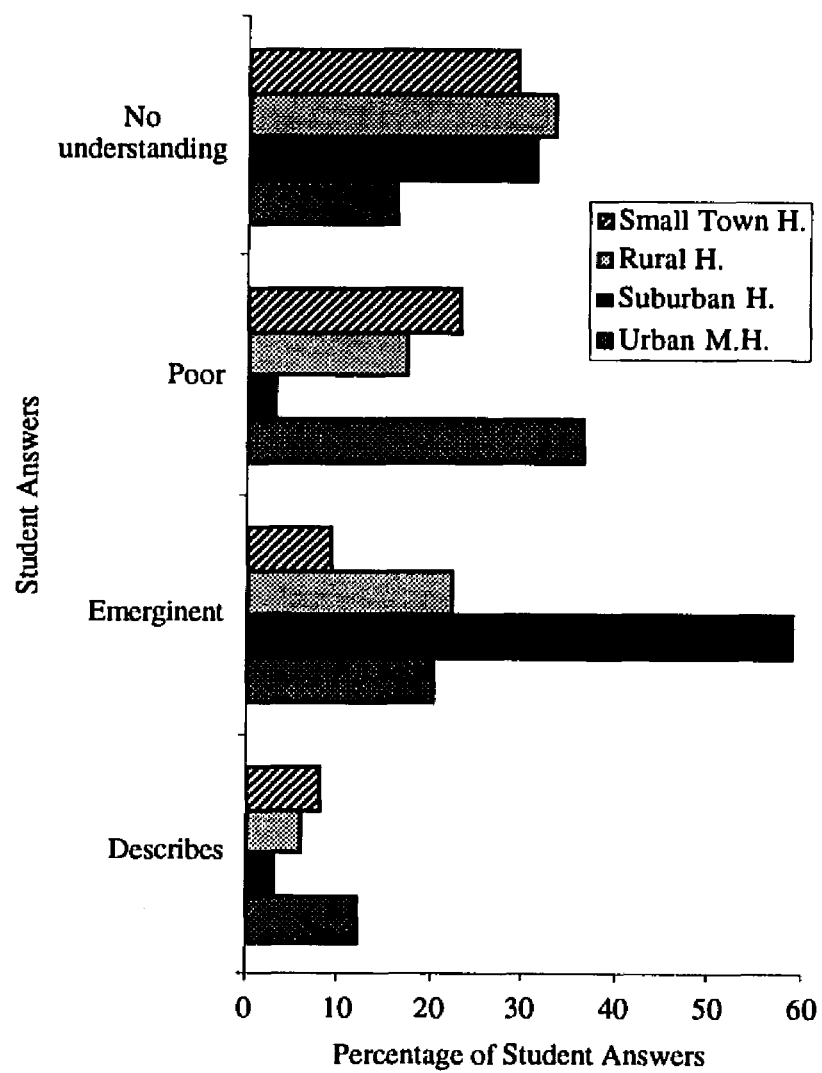


Figure 10. Student understanding of dead zones.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

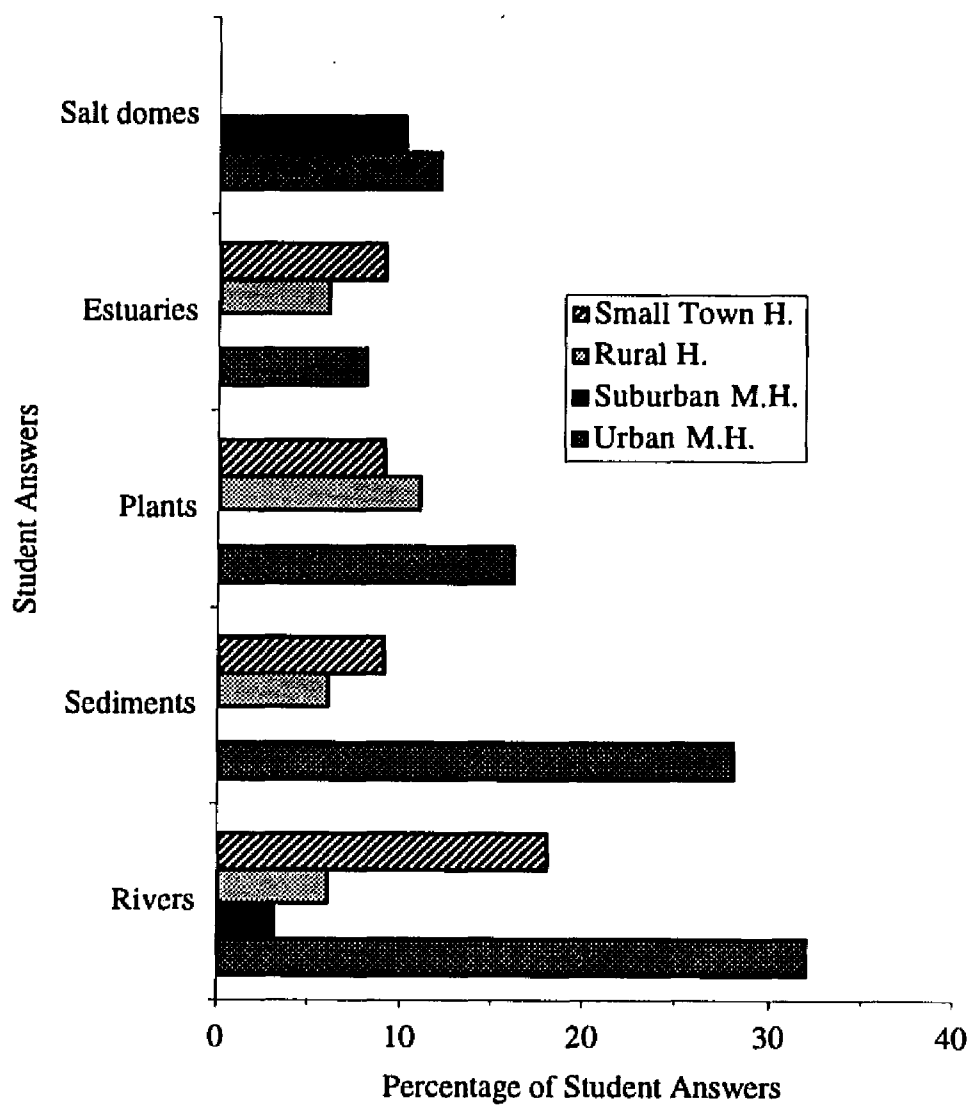


Figure 11. Top five responses for nutrient sources by school.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

plants. The understanding of nutrient sources is coupled to an understanding of hypoxia in the Gulf.

Plankton

The majority of all students (63%) consider plankton to be beneficial with 45% stating plankton's role in trophic structure (see Figure 12). Only a few students wrote about red tide or other toxic and noxious blooms. The cause and consequences of a plankton bloom is coupled to the limited understanding of nutrients and dead zones.

Barrier Islands

Numerous reasons were given for barrier island functions other than as a tourist attraction. The top two responses for all groups were storm protection (55%) and coastal protection (20%) (see Figure 13). The data suggest students had a good understanding of barrier island function and value (i.e., storm protection by wave abatement, acting as a dam to storm tides, nesting grounds for shore birds and sea turtles, and habitat for other organisms). Here is a good example of the integration of concepts--a physical feature connected to coastal erosion, economic issues, and ecological values.

Estuarine Dependence

For the concept of fish and shellfish dependence upon estuaries, nearly one-third of the Urban Magnet High (36%) and Small Town High (32%) students responded with the nursery role and as a reproductive site (see Figure 14). Of the remaining two schools, 22% of the Rural High students indicated estuarine dependence may occur because of sources of food.

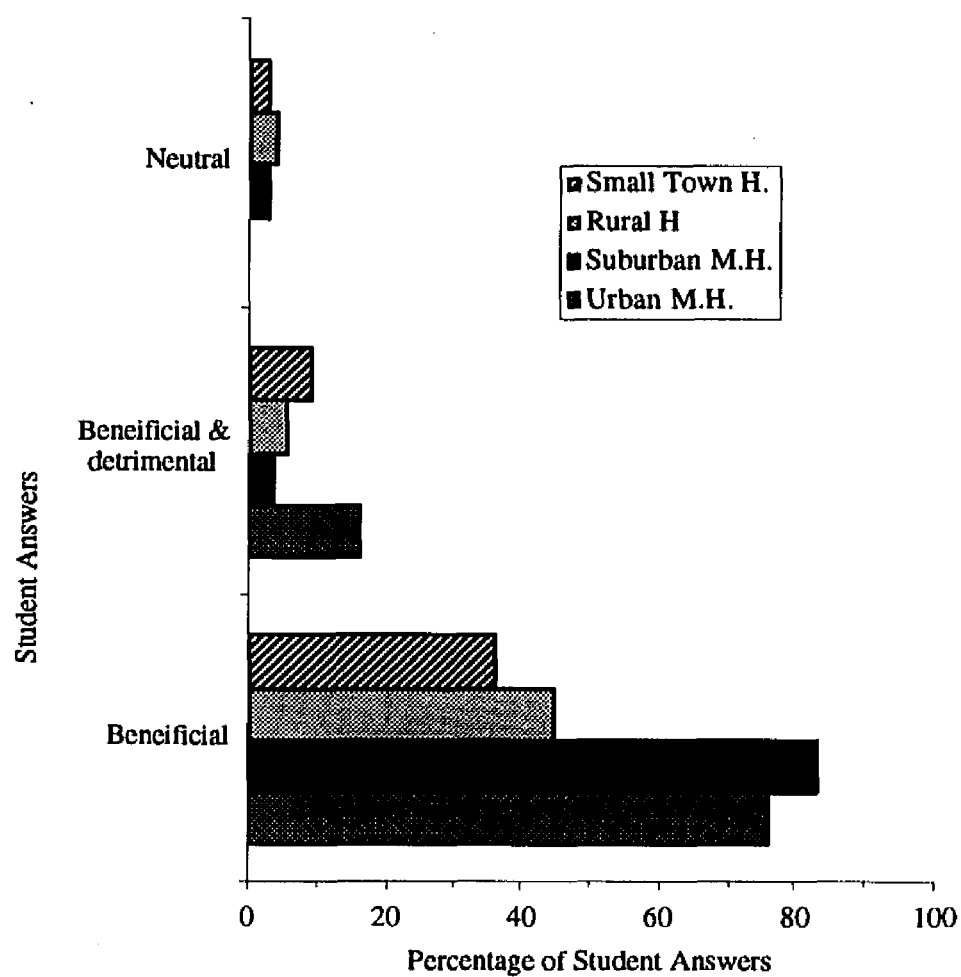


Figure 12. Responses to "Are plankton beneficial, detrimental, or neutral?"

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Urban responses for Neutral equals 0%.

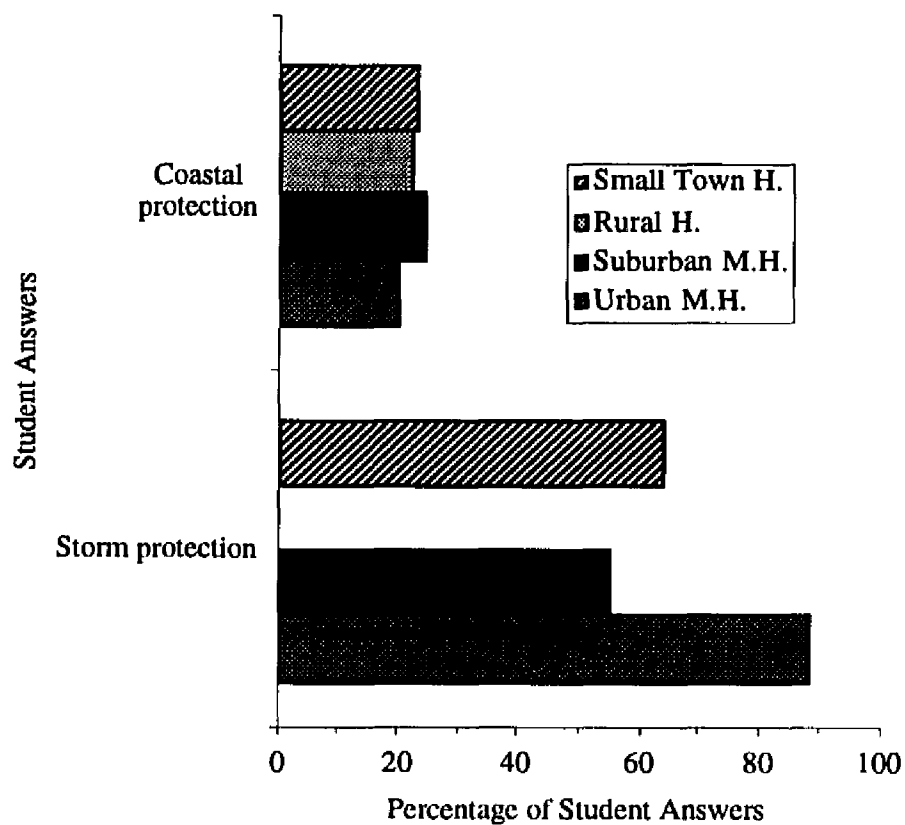


Figure 13. Responses concerning barrier island function.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Suburban responses for Storm protection equals 0%.

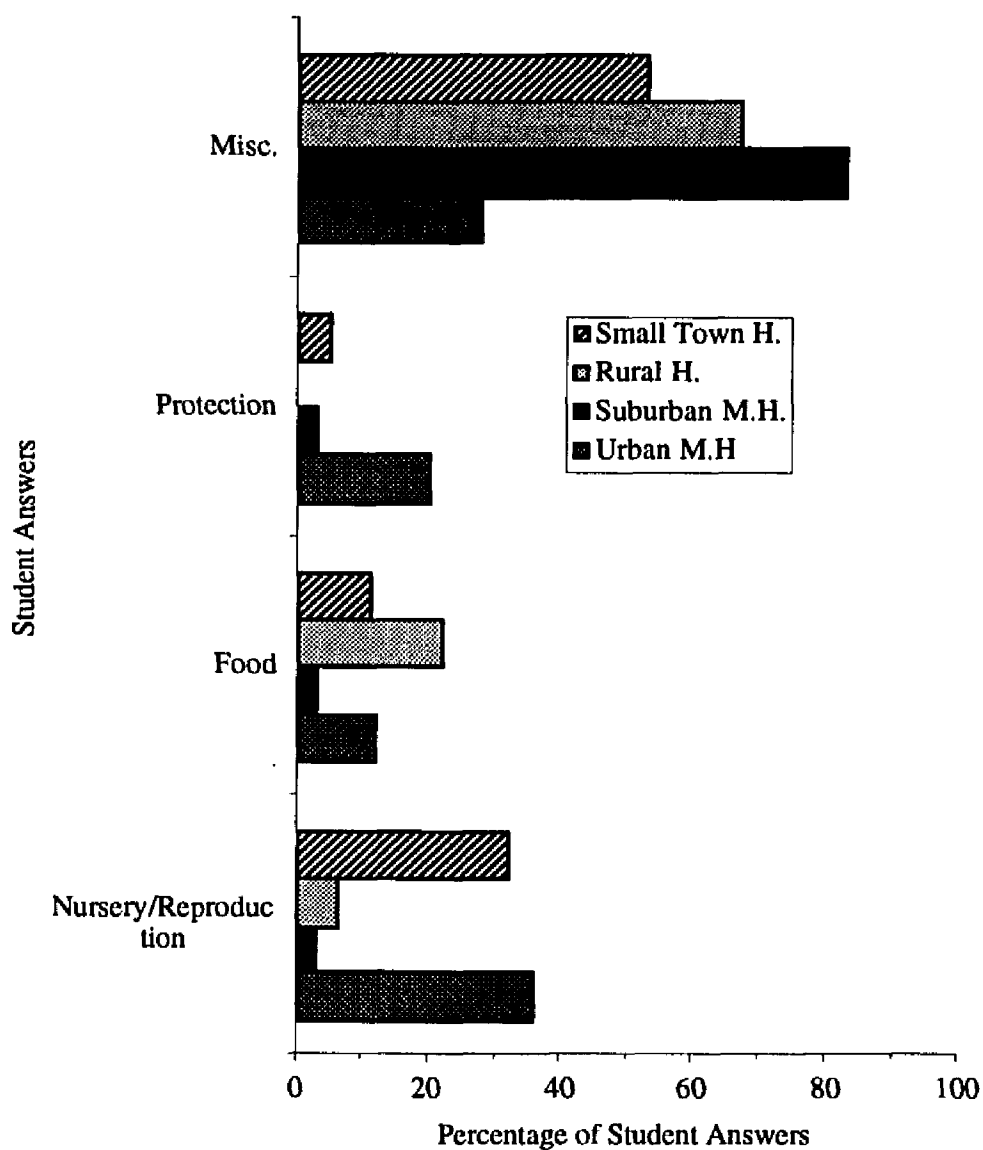


Figure 14. Reasons for estuarine dependence by fish and shellfish.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.
Suburban responses for Protection equals 0%.

Marine Debris

The idea that marine debris is harmful because of ingestion and entanglement was well developed in all schools with 55% of all students indicating such (see Figure 15). Other top responses were marine debris causes pollution and looks bad. Students probably are exposed to this problem more than other Gulf related environmental problems because of annual public beach sweeps.

Personal Concerns

For personal concerns related to the Gulf of Mexico the five largest response categories were; (a) pollution, (b) erosion, (c) marine debris, (d) storms, and (e) overfishing (see Figure 16). However, each school generated a long list of concerns with a range of 13-22 different responses. This reflects the concerns of each individual student giving the teacher or curriculum planner some insight into dealing with personal meaning and relevance.

Laws or Regulations

When students were asked about laws or regulations concerning the Gulf, all groups suggested regulations that focused on pollution, animal protection, and suggested fines and penalties for violations (see Figure 17). There are implications here for students' notion of justice. Admittedly, these students are enrolled in an environmental science class where an ethic of protectionism and conservation are more readily developed than exploitation and bottom line economics.

Volunteer Time

Students responded positively to a willingness to give their time to solve an environmental problem. Many were willing to give substantial amounts of time if necessary (see Figure 18). This reflects students' own

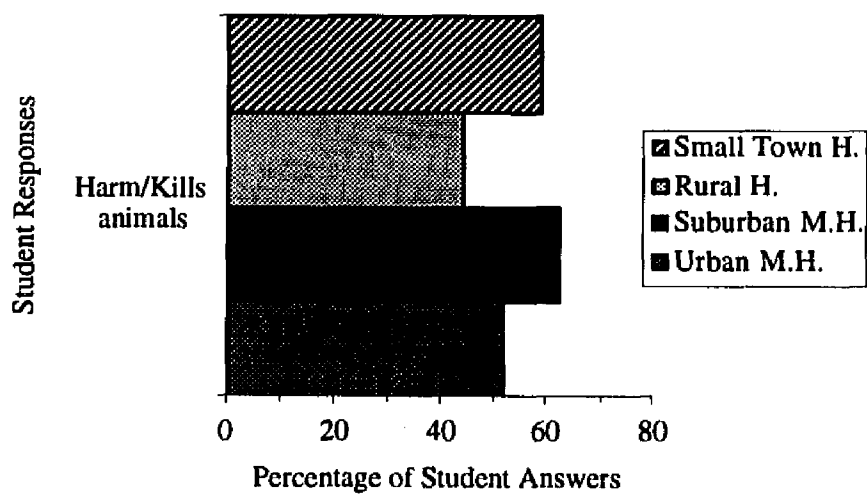


Figure 15. Responses to "Why is marine debris a problem?"

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

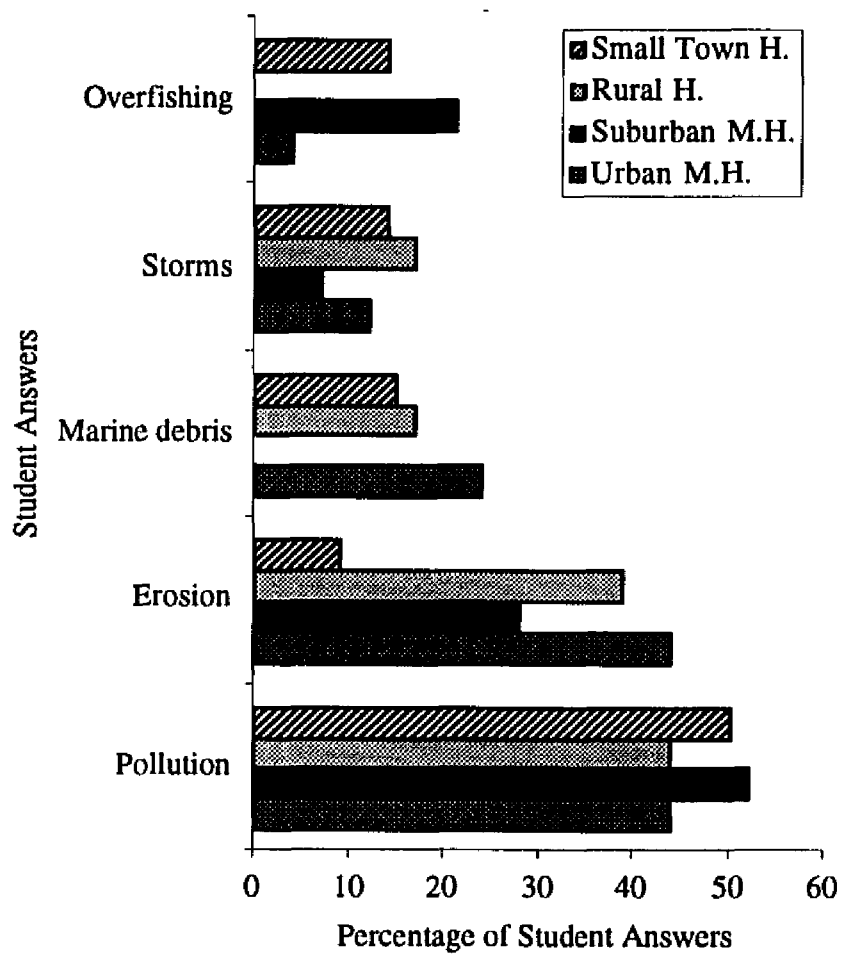


Figure 16. Concerns related to the Gulf of Mexico.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Suburban responses for Marine debris equals 0%.

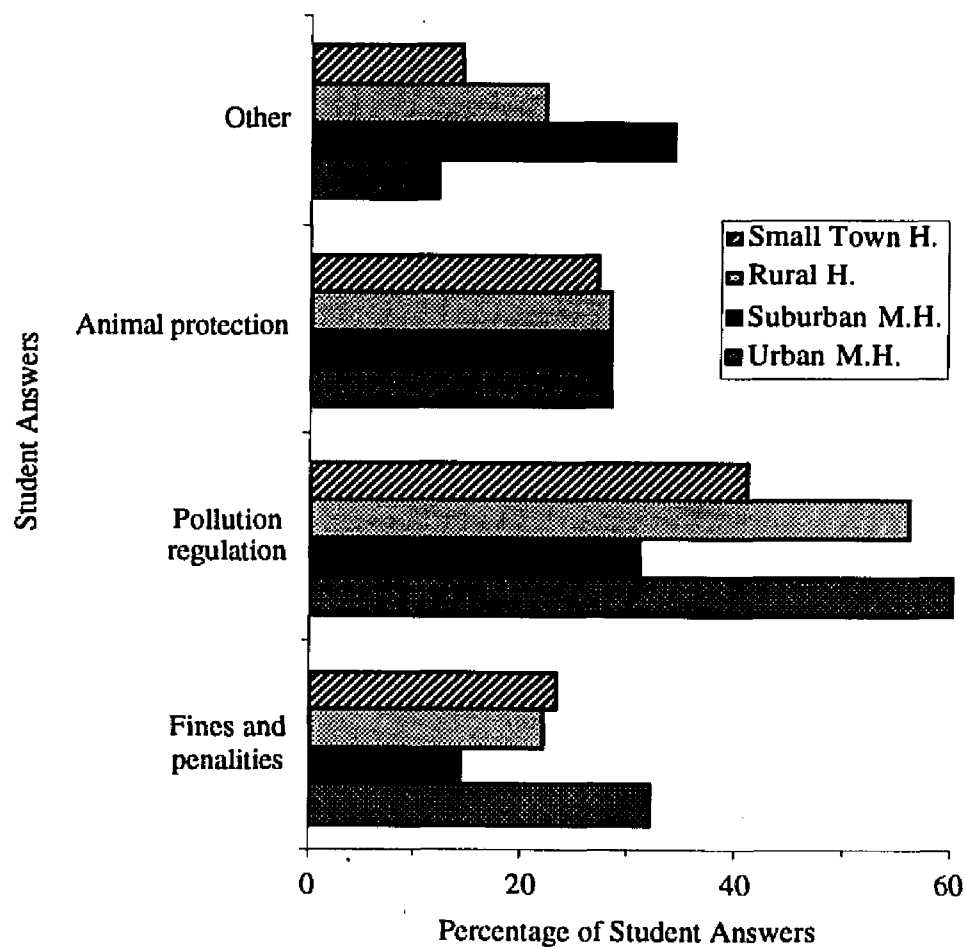


Figure 17. Laws related to the Gulf that students "would create."

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

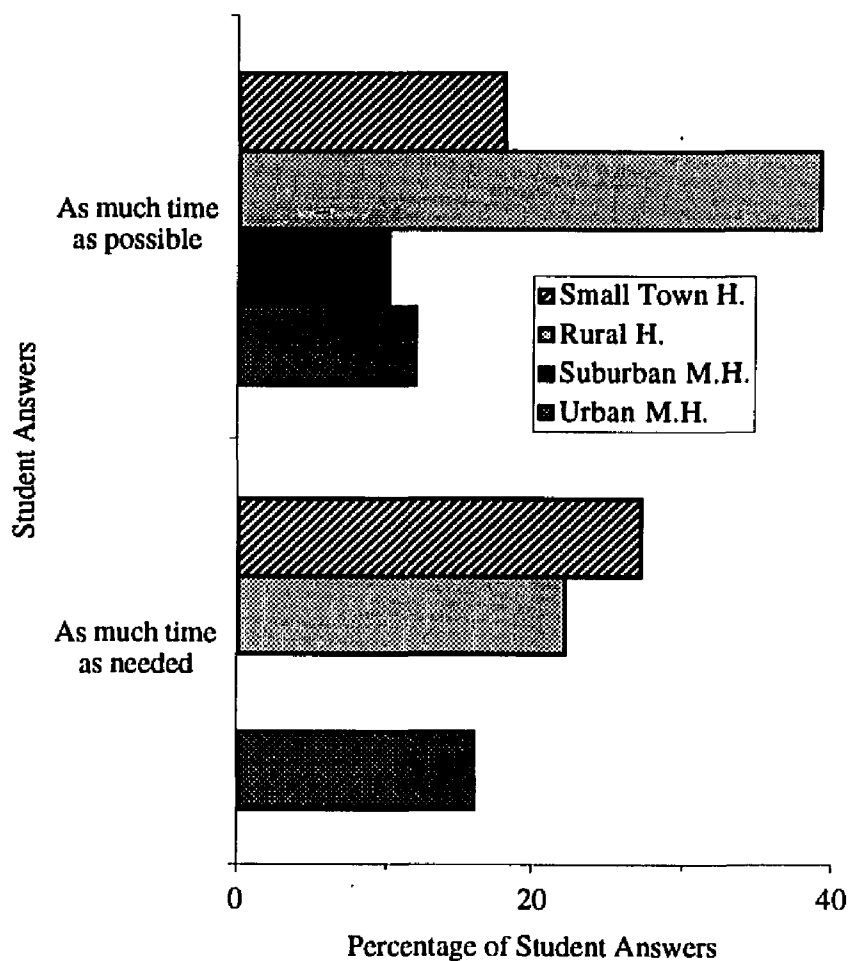


Figure 18. Time students were willing to devote to solving an environmental problem.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Suburban responses for As much time as needed equals 0%.

personal decision making processes related to Gulf issues. Further, this represents a potential untapped resource for environmental volunteerism.

What Students Want To Know More About Related To The Gulf

Top responses to what students want to know more about related to the Gulf include: (a) marine life, (b) marine mammals, (c) physical features, (d) pollution, and (e) barrier islands (see Figure 19). As in question No. 8 on the questionnaire, the responses reflected individual concerns of the students. This type of information would allow one to plan meaningful learning experiences for the students.

Graphics

Graphics that students found helpful were varied and their responses were widely distributed in terms of their descriptions such as, "the one with the animals on it." Concept maps were the top response for Urban Magnet High (20%) and Rural High (22%) (see Figure 20). A high interest in the bathymetry graphic was indicated by Small Town High (50%) and Urban Magnet High (20%) students. As part of the instruction and activities conducted during the ten day unit, these two schools constructed models of the Gulf using a bathymetric chart of the Gulf. Their experience with this graphic and the hands-on activity may account for their responses.

Hurricanes

Hurricanes were perceived as a threat despite modern forecasting ability because residents often decide not to evacuate or wait too long to evacuate (12%). Further, students mistrust weather forecasting and the unpredictable nature of hurricanes (43%) (see Figure 21). Students indicated that hurricanes were erratic and unpredictable as a basis for their views on hurricanes despite modern weather forecasting

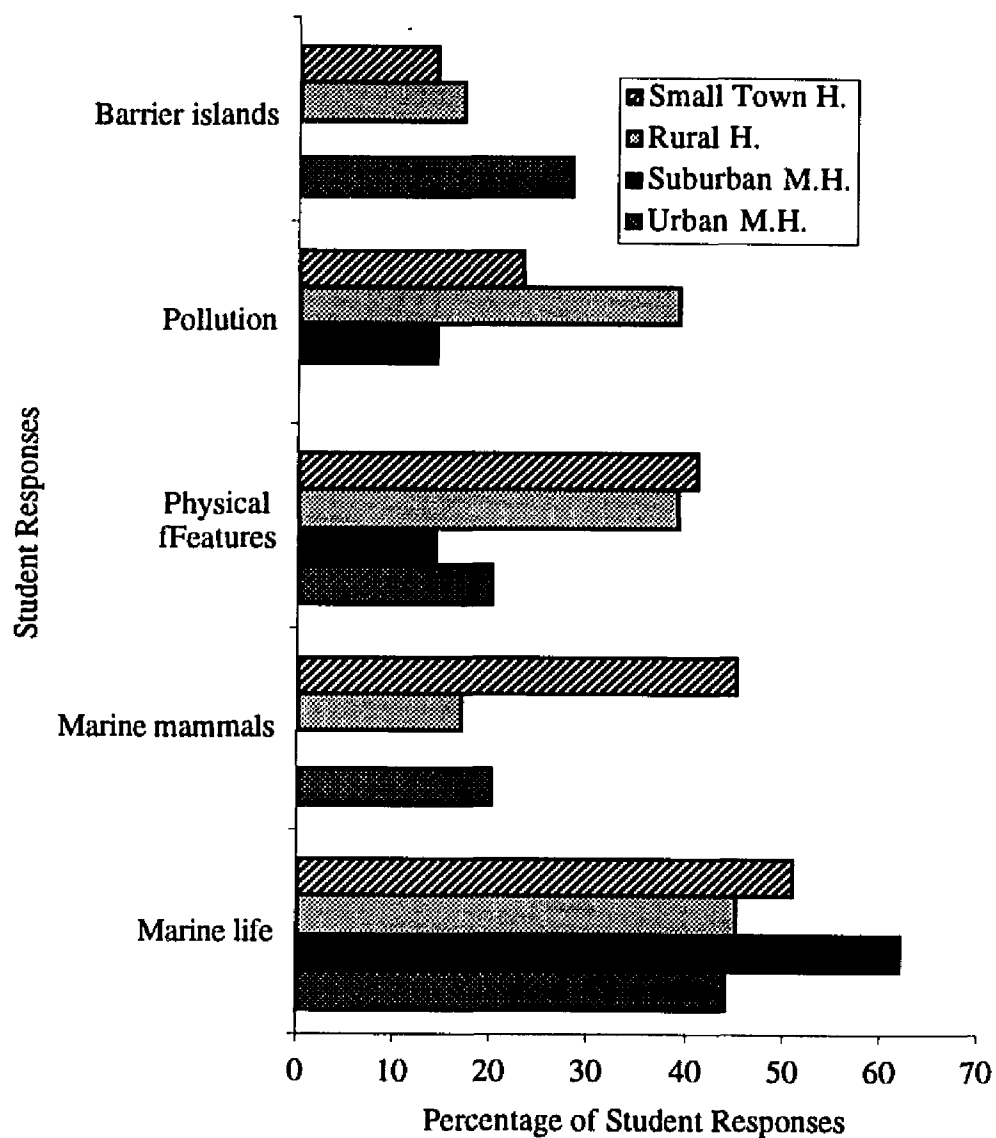


Figure 19. What students wanted to know more about related to the Gulf of Mexico (top five responses).

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Suburban responses for Barrier islands and Marine mammals equals 0%. Urban responses for Pollution equals 0%.

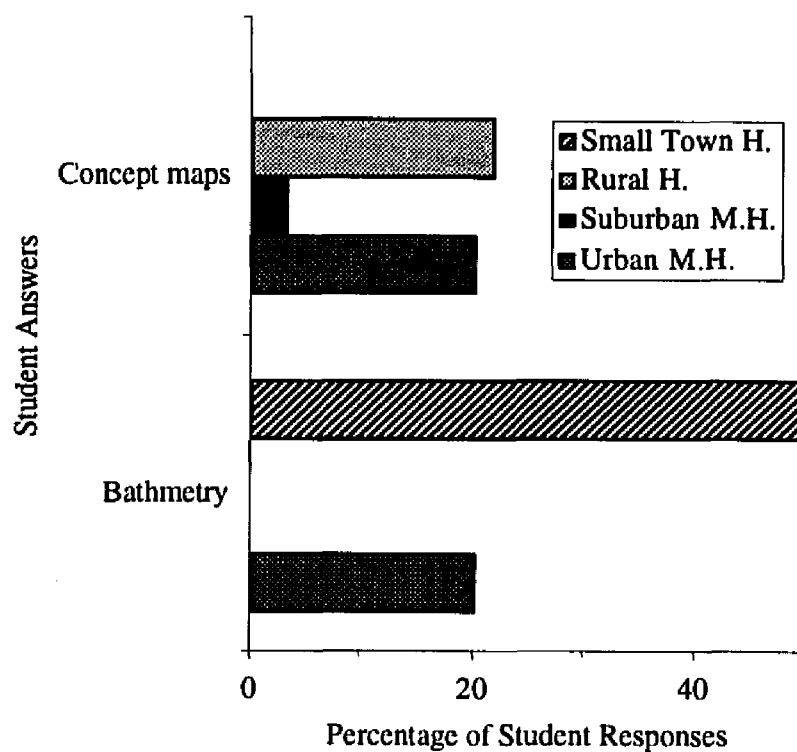


Figure 20. Graphics students found helpful or interesting.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Rural and Suburban responses to Bathmetry equals 0%.

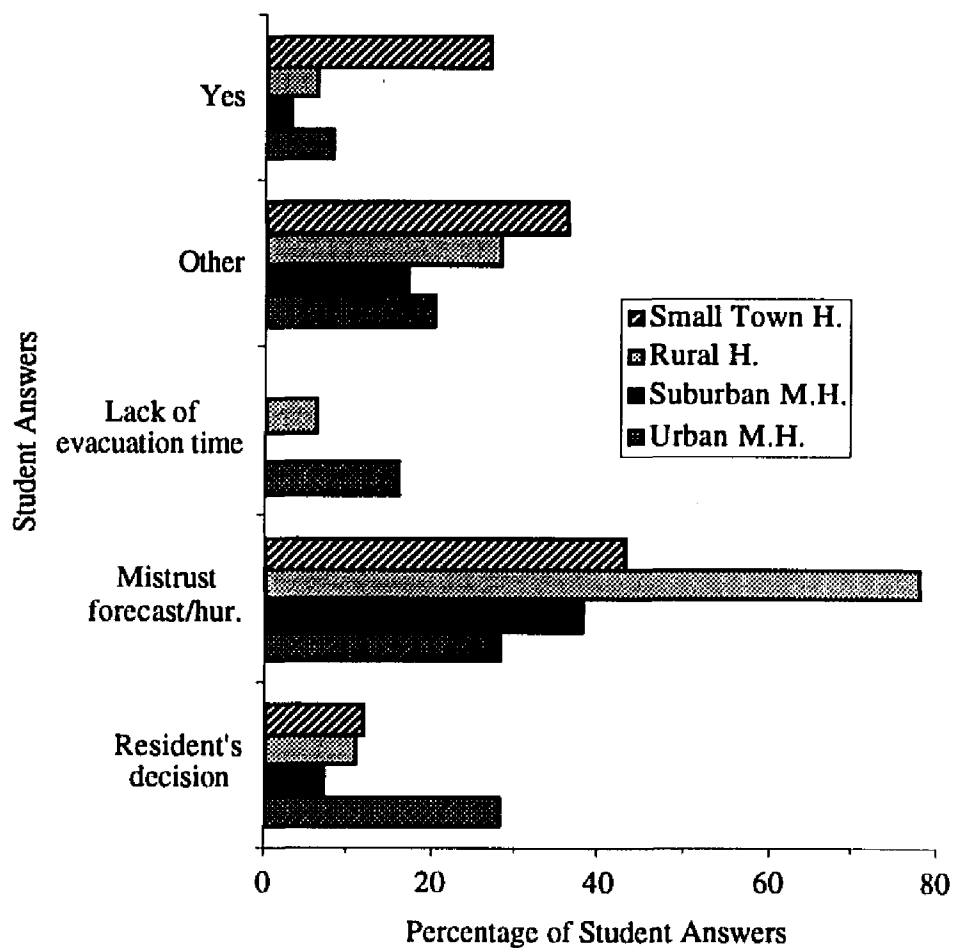


Figure 21. Student responses to hurricane safety question.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Small Town and Suburban responses to Lack of Evacuation Time equals 0%.

techniques. These responses demonstrated a lack of knowledge relative to hurricane warnings, hurricane watches, hurricane forecasting, and use of technology such as satellites and radar in this process. It can be argued that such knowledge should be part of Gulf literacy (to use scientific knowledge for personal decision making) and also for the purposes of public safety.

Likert-Type Scale Items

For the Likert-type scale items used in questions No. 14-25 on the questionnaire, responses are 1 = strongly disagree and 5 = strongly agree. Table 2 gives the question and the average response for all schools and each individual school. There are some responses that average out to a three as a neutral stance, but there are some very interesting agreements and disagreements with regard to the statements presented. Strong relationships were seen between personal action and the Gulf, relating habitat to fisheries production, lack of government response, freshwater flow and the Mississippi River, salt dome formation, and density differences in water.

Concepts Presented

A series of terms or concepts were presented--(a) bycatch, (b) TEDs, (c) manatees, (d) nursery area, (d) productivity, and (e) nonpoint source pollution and students were asked to associate the term and meaning. The students who responded gave a limited definition. The Small Town High group excluded several terms because of the teacher's lack of coverage. Level of response was low on these items. The teachers suggested since these items were last the students did not have time or were fatigued and distracted by that time of the class period.

For the term bycatch, 26% of the students responded in a manner indicating that the concept was developed (see Figure 22). In terms of an

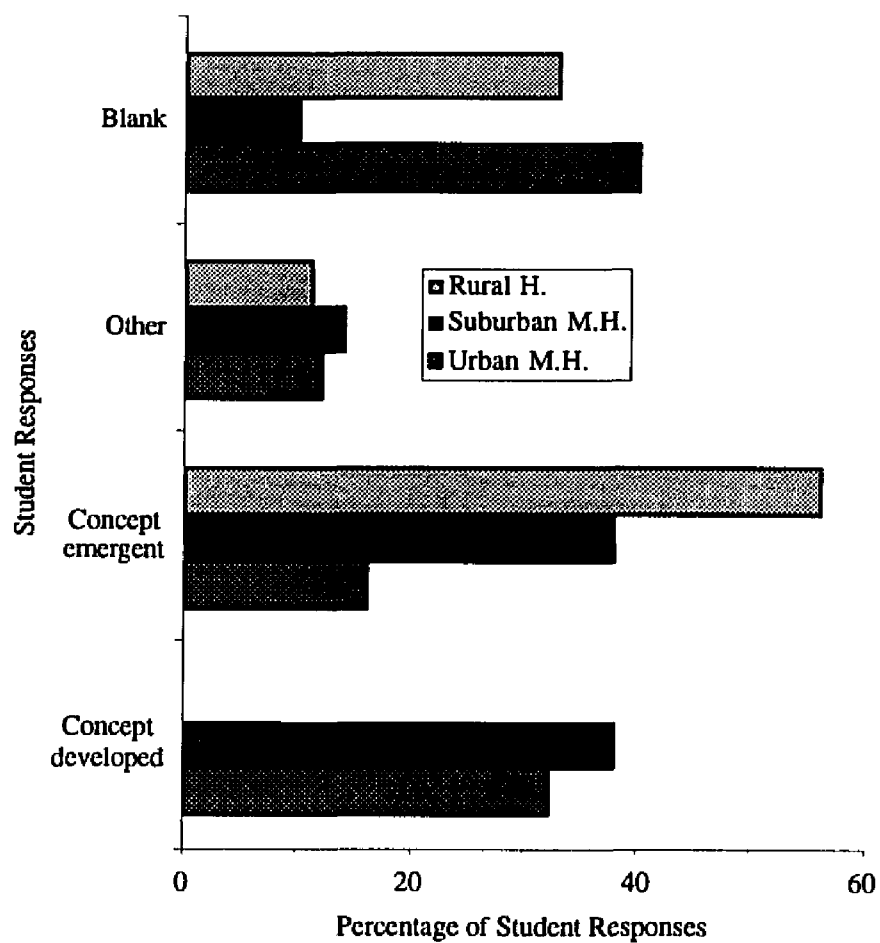


Figure 22. Student understanding of the concept bycatch.

Note: Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

Table 2
Summary of Likert-Type Scale Items

Question	All	Ur	Sub	R	ST
14. I have a personal connection to the Gulf of Mexico.	3	4	3	3	3
15. What I do in (Baton Rouge) has no affect on the Gulf.	2	2	2	2	2
16. I will try to stay current on issues related to the Gulf.	3	4	3	4	3
17. There is no connection between habitat degradation and fisheries production.	2	1	2	2	2
18. Graphics such as pictures, charts, and drawings help me learn concepts.	4	4	4	5	4
19. I would like to join a club or organization that tries to protect the resources and environment of the Gulf.	3	3	3	4	3
20. People should take a larger role in managing the Gulf.	4	5	5	5	4
21. The government at all levels seems to be doing a good job in managing the Gulf's resources and environment.	2	2	2	2	2
22. Freshwater flow into the Gulf of Mexico is mainly from the Mississippi River.	4	4	4	4	3
23. Scientists can easily predict a "red tide."	3	2	3	3	3
24. Water can actually stratify based upon differences in salinity and temperature.	4	4	4	3	3
25. Salt domes form over the course of thousands of years.	4	4	4	4	3
26. The origin of the Gulf Stream is in the Gulf of Mexico.	3	5	3	3	3

Note: Ur=Urban M.H., Sub=Suburban M.H., R=Rural H., and ST=Small Town H.

emergent idea of the concept, 35% of all students fit that criteria as judged by their responses.

The concept of TEDs was well developed across schools (average 57%) except for Small Town High in which there were no responses (see Figure 23). As with several of these concept questions the students wrote that they "did not go over this."

The concept manatee was recognized as a marine mammal by 40% of the total students (see Figure 24). It was also recognized as an endangered species by 21% of the students and vulnerable to boats by 26%. For a relatively unfamiliar marine mammal which they would rarely encounter except on trips to Florida, this shows encouraging progress toward a student constructed model of Gulf literacy.

The concept nursery area was developed in 14% of the total student and emergent in 36% (see Figure 25). This can be compared to question No. 6 where 19% of all students related nursery areas to estuaries.

Only a few students (17%) gave a description of biological productivity and that was mostly from two schools Rural High (33%) and Urban Magnet High (20%) (see Figure 26). Many answers were based on economics, natural resources, and various other interpretations. The concept presented by the researcher and the teacher should have been biological productivity to avoid confusion and give focus.

For the concept of nonpoint source pollution, 44% of the total students had a developed concept (see Figure 27).

Posttreatment Interview

Physical Characteristics

For physical characteristics of the Gulf of Mexico, the students interviewed (n=23) used a total of eight descriptors listed below (Table 3).

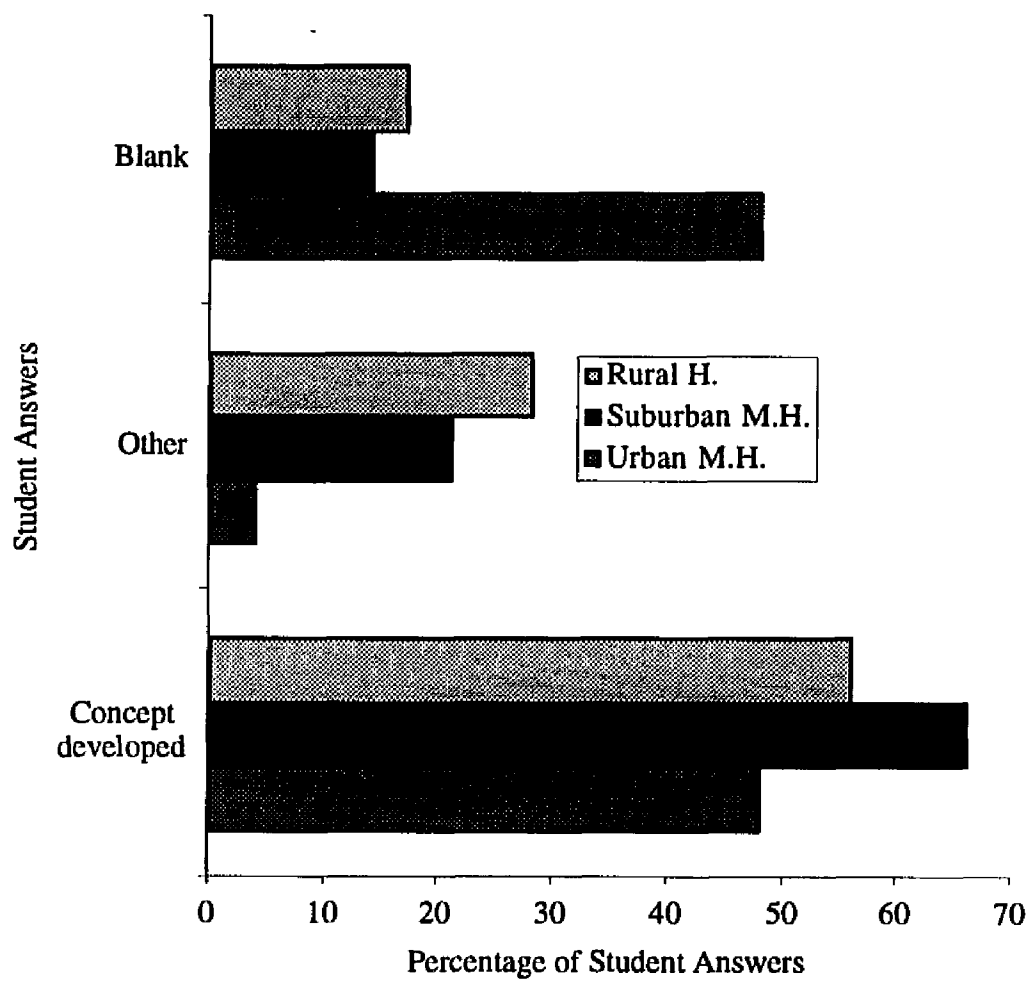


Figure 23. Student understanding of the concept TEDs.

Note: Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

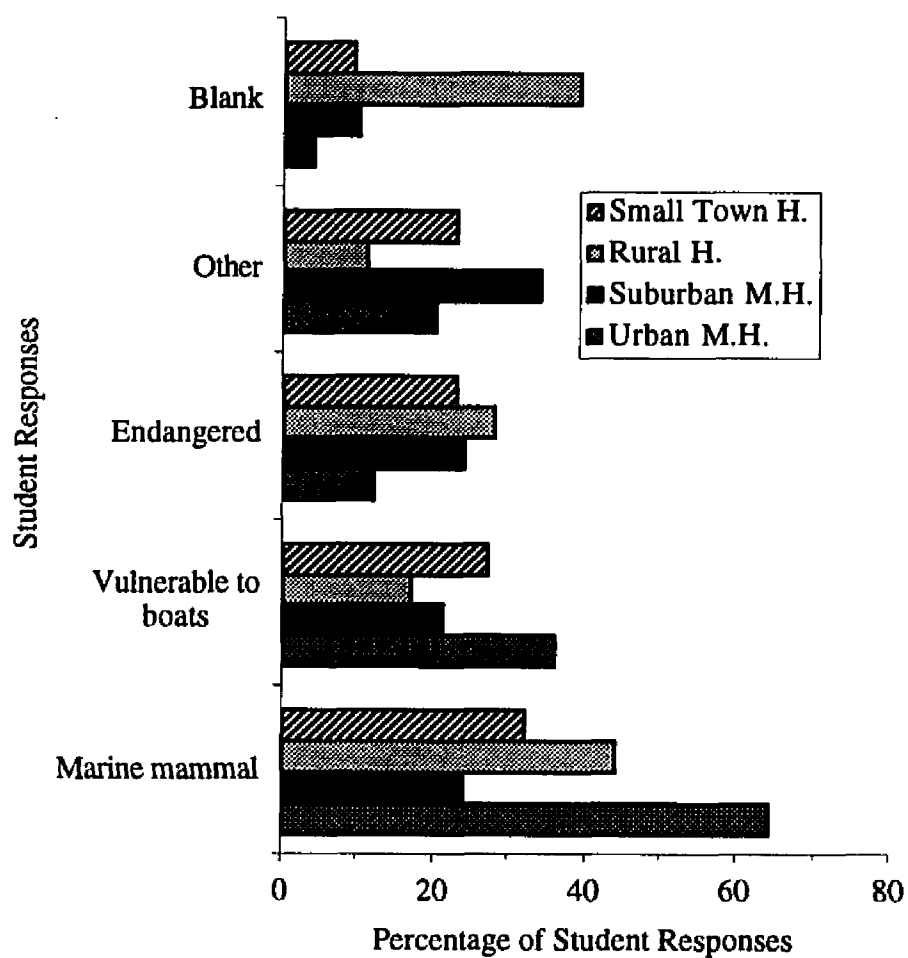


Figure 24. Student understanding of the concept manatee.

Note: Small Town $n=22$, Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

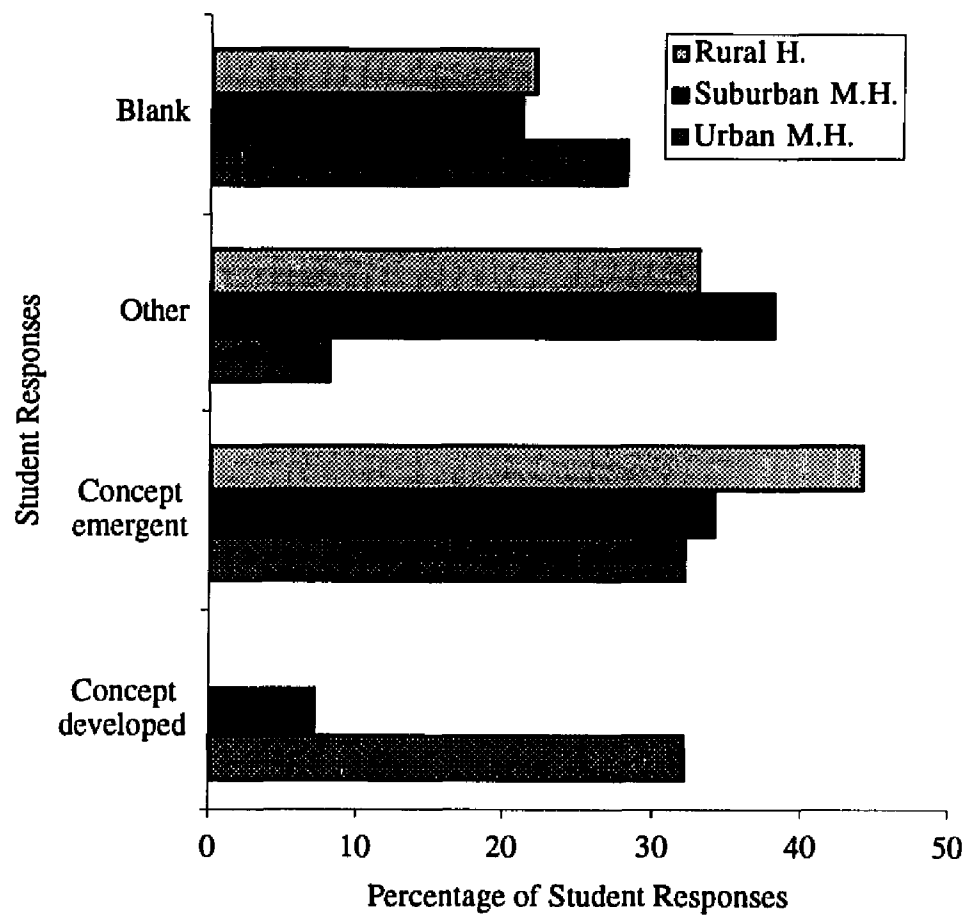


Figure 25. Student understanding of the concept nursery area.

Note: Rural $n=18$, Suburban $n=29$, and Urban $n=25$. Rural responses for Concept developed equals 0%.

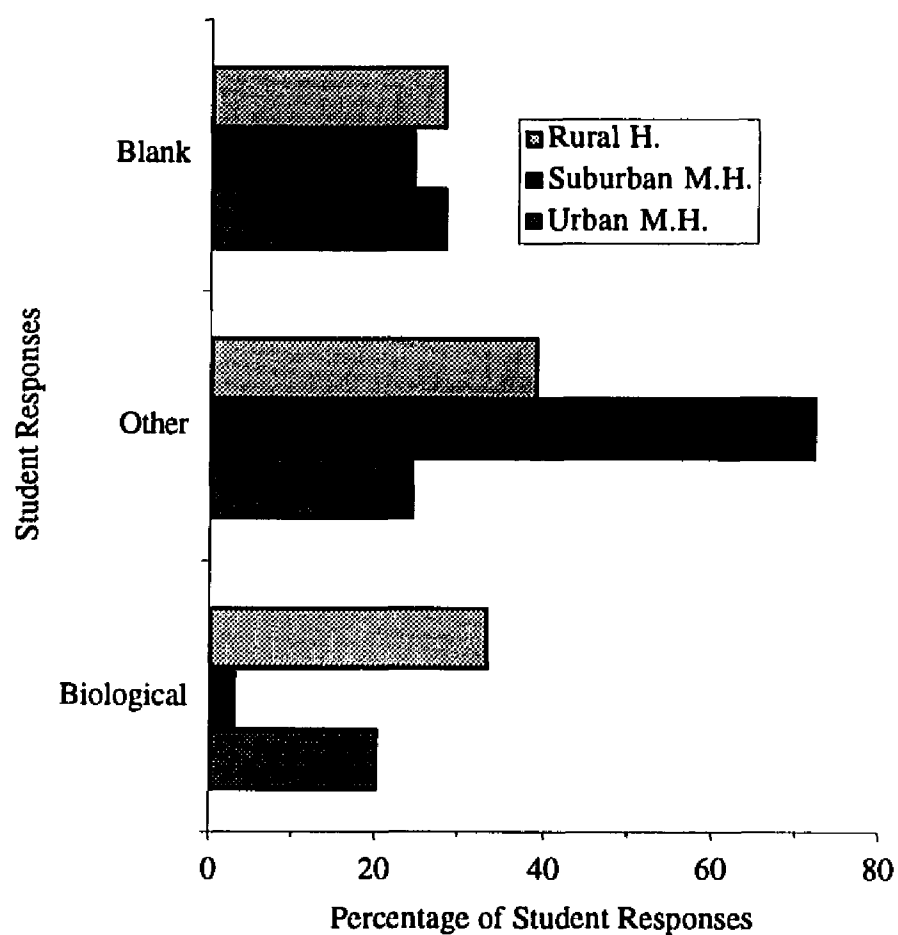


Figure 26. Student understanding of the concept productivity.

Note: Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

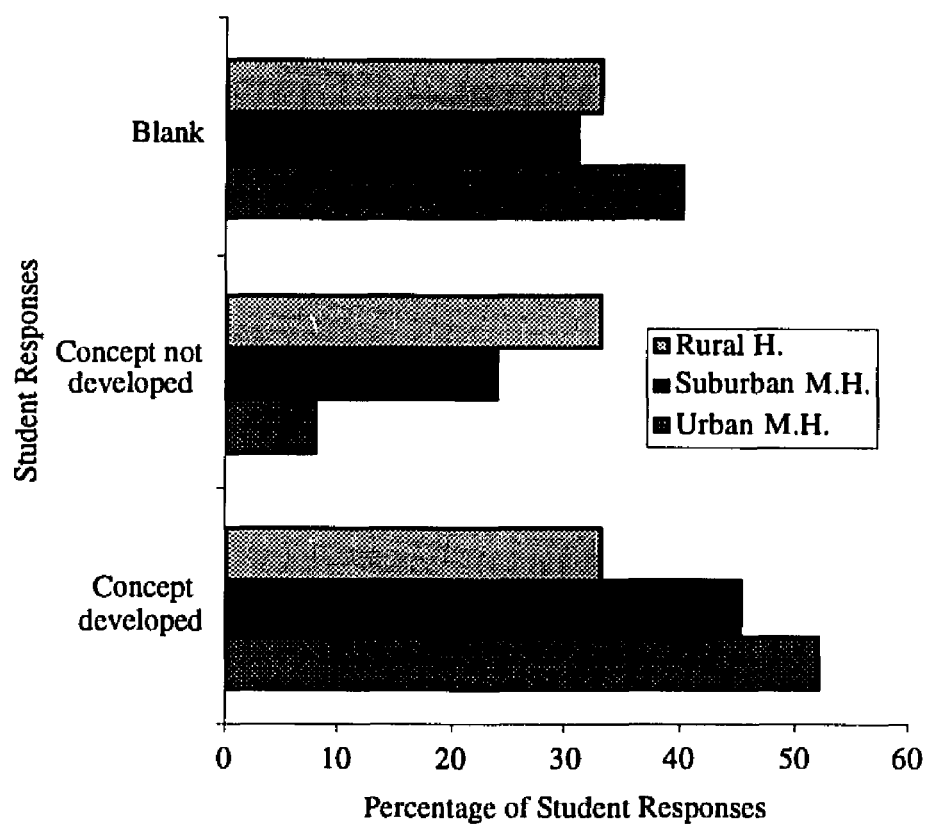


Figure 27. Student understanding of the concept nonpoint source pollution.

Note: Rural $n=18$, Suburban $n=29$, and Urban $n=25$.

Table 3
Physical Characteristics Used by Students

Characteristic	Number	% of n
barrier islands	8	35
estuaries	8	35
continental shelves	8	35
water	5	22
rivers	3	13
Mediterranean like	2	9
average depth	2	9

When asked about the continental shelf ($n=16$), five (31%) of the students were able to correctly point to where it would be on an outline map of the Gulf of Mexico that showed no features.

Rivers

Concerning rivers, the students ($n=19$) all stated the presence of the Mississippi River. Six students added that it was the largest. Eight other rivers were listed and four students stated there were over 40 rivers that empty into the Gulf. Top responses for what a river brings to the Gulf were: (a) sediment (49%), (b) freshwater (43%), (c) pollution (30%), and (d) nutrients (13%). When asked what nutrients are ($n=13$), only two students gave correct information such as one student's response of "help like in estuaries, good for plankton, can cause dead zones." Further, two students had an emergent understanding as indicated by the following responses: "a lot of nutrients come from the river and they get in the Gulf and estuaries . . . plants and animals take in the nutrients," and "there can be large amounts of them in estuaries." The remaining nine (69%) did not have a clear understanding of what nutrients are.

Dead Zones

Responses about dead zones ($n=22$) revealed seven (32%) of the students with emergent ideas, one with a fully correct idea, and 14 (64%)

with no clear idea. A response was classified as emergent if a lack of oxygen was mentioned in the response. For example, "where there is a lack of oxygen in the water and no fish."

Personal Concerns

When students were asked (n=22) about the personal concerns about the ecology or environment of the Gulf of Mexico, a range of ten different concerns was given (Table 4).

Table 4
Categories of Responses of Personal Concerns
About the Gulf Of Mexico

Concern	number	%
pollution	9	41
erosion	8	36
seafood	5	23
debris	3	14
marine animals	3	14
storms	1	5
marine mammals	1	5
oils spills	1	5
barrier island develop.	1	5
preserve its beauty	1	5

Commercial Fisheries

Students (n=22) responded to a query about the commercial seafood industry by mentioning eight types of seafood products with shrimp mentioned by 52%. Commercial fishing issues mentioned included: (a) economics (18%), (b) health concerns (18%), (c) TEDs (27%), (d) bycatch (14%), and (e) net ban (14%).

Estuarine Dependence

Students (n=19) were asked if they knew why shrimp and oysters are estuarine dependent. Six students gave correct responses, four had emergent ideas, and nine did not have a clear idea. An example of a correct response was: "for food supply and shelter." An example of a response indicating an emergent idea was: "they need estuaries to grow."

Staying Informed about the Gulf

Students (n=17) indicated that to stay informed about the Gulf of Mexico they would watch the news (53%), read newspapers (35%), read magazines (18%), and actually go to the place where a phenomenon was occurring (18%). Other responses included watching the weather channel, watching PBS, asking the teacher, asking a congressman, and asking experts. This indicates the students' knowledge base would be from authoritative sources. However, two students stated they would conduct personal research to seek an answer relating to the Gulf--clearly a goal of scientific literacy.

Graphics

In terms of the graphics used in the booklet, the students (n=22) stated they liked: (a) bathymetry chart (23%), (b) ocean basin features (14%), (c) life cycles (14%), (d) concept maps (9%), (e) fishing industry graphics (9%), (f) river input (9%), and (g) barrier island erosion (9%).

Relationship to Gulf

When students (n=21) were asked if they had any affect the Gulf of Mexico and if the Gulf of Mexico had any effect on them, four top categories of responses were: (a) any pollution in a watershed eventually ends up in the Gulf (62%), (b) Gulf affects our weather (43%), (c) relationship to fishing industry (43%), and (d) economics (14%).

Concept Map Analysis

At the conclusion of each posttreatment interview the students were asked to construct a concept map with the help of the interviewer. The students were given the superordinate concept of "Human Impacts" and asked to generate related concepts and examples. A total of 23 concept maps were constructed (see Appendix F). The concept map was photographed using a Polaroid™ camera and redrawn using a computer graphics program (MacDraft).

Maps were analyzed in terms of the following criteria: (a) number of elements such as concepts and/or examples, (b) number of examples, (c) number of cross links, (d) levels of hierarchy, (e) number of elements common with "Human Impacts" concept map in the booklet, and (f) a summary of all terms used in concept map construction. This information is summarized in the tables below (Tables 5 and 6).

Table 5
Summary of Concept Map Elements

Criteria	<u>Total</u>		<u>School</u>			
	av.	range	UH	SH	RH	STH
concepts/examples*	11	7-16	11	11	10	8
examples	1	0-5	1	2	1	2
cross links	1	0-4	2	2	0	1
levels of hierarchy*	4	3-6	4	4	3	4
common elements	3	1-6	3	3	3	2

Note: * Does not include superordinate concept. UH=Urban M.H., SH=Suburban M.H., RH=Rural H., and STH=Small Town H. (n=23)

Table 6
Most Frequent Terms Used In
Concept Map Construction

<u>Term or Category</u>	<u># used</u>
animals	24
pollution	16
oil & gas	15
marine mammals	11
fishing	8
commercial fishing	7
debris(trash)	7
barrier islands	6
recreation	6
erosion	5
industry	5
overfishing	5

Note: n=23

Since concept maps are idiosyncratic constructions, a range of elements can be expected. However, between the four schools the range was much narrower than between individuals. For instance there was a range of 8-11 (average) concepts/examples between the schools as opposed to 7-16 between individuals. The levels of hierarchy may be an artifact of the board space provided or it may be representative of the range of human vision. One analogy may be that levels of hierarchy are like trophic levels once an element is removed so many levels away from the superordinate concept or top of the trophic structure it loses significance or meaningfulness.

The number of common terms between the students' maps and the "Human Impacts" map provided in the instructional booklet was examined as a measure of what the superordinate concept "Human Impacts" would evoke. Again allowing for idiosyncratic construction a wide range can be expected. With regard to the most frequently used terms, five of the

twelve listed in Table 6 are not on the "Human Impacts" map. However, these five terms--fishing, commercial fishing, barrier islands, marine mammals, and recreation--are integrated easily under the superordinate concept "Human Impacts." In fact this represents student integration of concepts into this map suggesting integration of concepts under the larger organizing concept of the Gulf of Mexico.

It should be recognized that these students were novice mappers, which may account for the low number of cross links and examples. Many students, despite some experience with concept maps during their unit, needed encouragement. Some felt like they were being tested. However, once their elements were placed on the map, they were comfortable with editing the map. Almost every student was proud of his/her map and appeared impressed that he/she knew so much. Many also recognized the generative qualities of mapping stating that once they had a few concepts down the others "just sort of came."

Teacher Interviews

The four cooperating teachers were interviewed to obtain their insights, opinions, and comments relative to the actual teaching of the unit, use of the booklet, and the compiled results. A bulleted summary of their comments appears below. Many of their comments have implications for further teaching.

Small Town High

- loved doing the ocean basin model
- trouble converting meters to feet
- students didn't realize depth of the Gulf
- students didn't realize there were so many rivers emptying into the Gulf
- low readers had problems
- need pictures

- loved barrier island activity
- did not get estuaries (rushed throughout it)
- need more time
- resistance to concept mapping from previous bad English course experience
- many students have not been to the coast
- teach more positive things
- use actual reprint of articles
- personally learned a lot about concept development and finding mapping useful
- plan to teach more meteorology
- will use more open ended questions for assessment
- did not spend much time on dead zones

Urban Magnet High

- could use short video clips
- really like water density demonstration
- agreed their hands-on experience with the bathymetry model made them more likely to choose that as a graphic they liked
- rivers as sources of nutrients are hard to envision
- poor understanding of dead zones relates to a vocabulary problem
- to better understand estuaries as a nursery area superimpose life stages over the waters
- include what good is being done

Rural High

- rushed through dead zones, not easy to understand, poor background
- estuarine dependence not emphasized
- surprised by lack of hurricane forecasting confidence, these students pay attention to the weather because they are hunters and fishing persons, also showed a film on Betsy
- these students are exposed to a lot of flooding
- book needed photographs
- impressed with student concept maps

Suburban Magnet High

- fascinated by salt domes
- should have a high understanding of estuaries because they [students] tied in food chains, the terms were familiar to them

- seems like the concept map help you to organize your thoughts
- tried to collect personal stories about hurricanes
- tied commercial fishing to the economy

DISCUSSION

Gulf Literacy Model Development

The development of the model of Gulf literacy was informed by current definitions of scientific literacy, experts in marine science and education, and a content analysis of newspapers along the U.S. Gulf Coast. Initial model development consisted of a set of concept maps that were constructed to represent the model as a conceptual framework. All concepts in that framework were verified through the interviews and content analysis processes.

Current models of scientific literacy emphasize: (a) understanding key concepts and pervasive principles of science; (b) understanding newspaper articles and graphics related to science issues; and (c) using scientific ways of evaluating evidence for individual and social purposes (AAAS, 1989; Demastes & Wandersee, 1992). The construction of the concept maps and the expert interviews served to develop (a) listed above. The content analysis helped to develop (b) above. The booklet and its activities helped to develop (b) and (c) above.

The content analysis showed variation in frequency of topics among the four locations, except fisheries issues that occur frequently at all locations. Though there was variation from one location to another the topics or issues were all shared concerns. For example, Corpus Christi had just gone through the *Mega Borge* oil spill that generated more articles at that location. Mobile was going through EPA and locally assisted efforts to lower discharges of industrial and sewage effluent waste into Mobile Bay. Therefore, at the time, Mobile was more sensitive to pollution issues as reflected by the number articles printed. These issues

may have a tendency to shift from one location to another, but they are commonly shared at all locations along the Gulf.

The content analysis helped inform the model and supply information to the development of the booklet. Also, the analysis of Gulf coast newspapers at various locations grounded the model in reality. These are real issues occurring at real locations. The frequency of the reporting also gave an indication of the strength of these issues or topics. Hence the model is inherently relevant and meaningful.

Similarly, expert interviews informed the model by generating a list of concepts and issues that students leaving high school should know about the Gulf of Mexico. Since these are people whose work involves the Gulf of Mexico, the information they provided was considered current and of immediate concern. Though most of the experts were leery of newspapers, they agreed the issue reported is usually important it is the sensationalism and bias that is more their concern.

As part of the introduction to this research project, three possible pervasive themes were proposed as outcomes of this project (see p. 4: (1) results of human behavior, (2) nonpoint source pollution, and (3) fisheries management). All these topics emerged in the developed model and student model of Gulf literacy.

Instructional Utility

On the basis of upon the interview data from students and teachers the booklet and the unit on the Gulf of Mexico were well received. All the teachers gave positive feedback about the booklet. The teachers made several suggestions for improvement that can be incorporated at a later time. Three of the four teachers said they will use it or materials from it

next year. The fourth teacher is moving but she is interested in using concept mapping again in her new courses.

Student Model of Gulf Literacy

Biological literacy model

From the data, we can formulate the students' collective model of Gulf literacy. The first formulation is done by comparison with the BSCS model of biological literacy referred to earlier (see Figure 1).

Characteristics of "nominal biological literacy," the first level in the biological literacy model, includes knowledge of terms or concepts, but knowing them in name only. Terms or concepts have no meaning or importance. Students possess misconceptions and provide naive explanations of biological concepts. Pretreatment interviews revealed similar characteristics in the students of this study. For example, many students stated they had heard of the term estuary, but could not give an adequate explanation. They recognized that barrier islands were subject to flooding and vulnerable to hurricanes, but did not understand the protection function of these islands to interior wetlands and populated areas. Their physical-geographical descriptions of the Gulf were poor. They were not able to articulate a general size, estimate its depth, or name many of the numerous rivers that input the Gulf. This is the level where most students were before the unit was taught.

The next level of literacy proposed by the BSCS (1993) is called "functional literacy." Students at this level can define terms or concepts but still have a limited understanding of or meaningful experience with them. This is seen in this study by the number of categories developed to characterize responses labeled "emergent understanding." Examples are the concepts of dead zones, bycatch, and nursery area. The category

"emergent understanding" included answers that were partially correct, may need further explanation, or demonstrate some limited understanding. For the concept dead zones the following responses were categorized as emergent: "Where there is a lack of oxygen in the water and no fish" and "Areas of low oxygen. I'm confused about it and red tides. Sometimes fish are caught next to the shore." Both these examples mention low oxygen without causation or further explanation. Therefore, they were classified as having an emergent understanding of the concept "dead zones" (hypoxia).

"Structural biological literacy" is the next level proposed by the BSCS. At this point students understand the conceptual schemes of biology and understand procedural knowledge and skills. They should be able to explain biological concepts in their own words. They should use such knowledge in novel situations. It is the foundation to learning other related information in and outside the formal school setting. At this point boundaries between functional and structural literacy become blurry. Students may be at a structural level of Gulf literacy with respect to some concepts, but they may be functional or even nominal for other concepts. In the development of concept maps many students were given the opportunity to structure their knowledge about the major proposition of human impacts related to the Gulf of Mexico. While the given model in the booklet did not include recreational aspects, several students included recreation on their maps. Therefore, the students were able to generate their own personal propositions regarding human impacts. Students developed personal relevance to the Gulf as demonstrated by their own perceptions of being connected to the Gulf through their influence on the Gulf and the Gulf's influence on them. Their influence was demonstrated

by describing a watershed as their connection. Many students stated that if they were to pour something out it would travel through streams or sewers to a larger body of water eventually emptying into the Gulf. The largest effect the Gulf had on the students was weather related such as storms and economics through jobs created by the fisheries and mineral exploration. The connection to the Gulf via watershed and return influence through weather provides evidence of a foundation of personal relevance and experience. An interesting side issue is that these perceived connections are foundational to understanding the water cycle.

"Multidimensional biological literacy," the highest level of biological literacy, is characterized by students wanting to learn more about a concept, act on a problem, develops questions related to a biological concept, commit to learn more, or develop a plan of action to solve a problem. This means that the student must recognize personal deficiencies in knowledge or skills, seek the answers or skills, and apply the knowledge or skills. This may seem like an idealized state where students are self actuating and showing initiative beyond the scope of their traditional instruction, but this is what a scientifically literate person should do. The students in this study were emergent in this respect. When students were queried about their personal concerns related to the Gulf of Mexico, approximately 50% of the students in all four schools mentioned pollution. Erosion and marine debris were the next largest concerns. When asked where they would seek information, the students stated television news, newspapers, and magazines. This indicates that students know how to stay informed. While there is mistrust attributed to newspapers by some of the experts that were interviewed, the ability to read and understand articles of scientific issues is part of the definition of

scientific literacy. Almost all students were willing to devote personal time to help solve an environmental problem. Many were willing to devote considerable amounts of time (see Figure 18). The students in this study exhibited a degree of multidimensional literacy only in respect to intent and affective concerns. They wanted to learn more and wanted to help if needed, but the actual observation of a students recognizing a knowledge deficiency and than the actual seeking of information to reconcile this deficiency did not occur within the time frame of this study.

Conceptual Model

A second comparison to help formulate the students' collective model of Gulf literacy is done by examining the conceptual model proposed in the booklet and students' understanding of these concepts as determined through interviews, questionnaires, and concept maps. The concepts will be examined using the framework of the four major superordinate concepts used to organize a framework of understanding the Gulf (physiographic features, chemical/physical processes, biological productivity, and human impacts).

The first superordinate concept is "physiographic features." From the questionnaire data (see Figure 9) the students were able to describe the Gulf of Mexico in terms of its (a) barrier islands, (b) estuaries, (c) saltwater, (d) salt domes, and (e) rivers. However, there is variability between the schools and the usage of a particular feature. The Urban Magnet High students have the most frequent use of the above terms except for the term saltwater, however 80% of the Suburban Magnet High students used that term. Small Town High had the next most frequent use of the above terms. From the interview data the top terms or descriptors used were: (a) barrier islands, (b) estuaries, (c) continental shelves, (d)

water, and (e) rivers. Common to both the interview and questionnaire data are the terms barrier islands, estuaries, rivers, and water. The descriptor continental shelf was actually seventh on the list generated from the questionnaire data, but the term salt domes did not appear in the interview results.

The data suggest that Urban Magnet High students may have a stronger conceptual framework of the physical features of the Gulf of Mexico. From the teacher interviews it was revealed that Urban Magnet High and Small Town High were the only two schools to actually construct a model of the Gulf of Mexico ocean basin using an activity from the booklet. This may explain their strength in this area. Further, the teacher from Suburban Magnet High emphasized more of a chemical and water pollution approach to her teaching that may account for the high frequency of the term saltwater in describing the Gulf. She did do the various water density activities from the booklet.

For the superordinate concept "physical and chemical features," concepts were developed at various levels. For the concept dead zones a good descriptive understanding was absent across all schools as evidenced by questionnaire and interview data (see Figure 10). Suburban Magnet High did demonstrate a strong emergent understanding of the concept. All the teachers agreed that this was a difficult concept to teach and for the students to understand. To fully understand this concept several concepts need to be correctly understood such as nutrients, biological productivity, phytoplankton, dissolved oxygen, bacteria, thermocline, and density of liquids. Student understanding of the concept productivity was poor across all schools. One explanation may be many answers were given in the context of factory or economic productivity instead of biological

productivity. The concept dead zone also requires the integration of the above concepts. This difficult but important phenomenon necessary to understand the Gulf is characteristic of what is called a "critical juncture."

A critical juncture may be defined as a conceptual watershed that divides students into two groups on the basis of their prior understanding of foundational concepts relevant to those currently being taught. Where these prior concepts are essential to future learning, students may or may not be able to demonstrate holistic, unified understanding of course content beyond such a juncture (Trowbridge & Wandersee, 1994). In this case the holistic understanding is Gulf literacy.

The posttreatment questionnaire asked the students to list sources of nutrients. The wide range of responses plus the low frequencies of responses listing rivers as a source indicate a poor understanding of nutrient sources. The response "plants" was interpreted as chemical plants inferred from the interview data. Again, nutrients and their sources are critical to understanding other concepts such as dead zones, biological productivity, blooms, and red tides.

While students were very aware of storms and hurricanes, they also did not feel modern forecasting gave them any security. There was a large degree of mistrust in weather forecasting (average 43% of the students). Further, hurricanes were characterized as being unpredictable. Other factors that made coastal residents unsafe listed by students were; a resident's decision to stay and lack of evacuation time. The Rural High students had the highest frequency of (78%) listing mistrust in weather forecasting. The classroom teacher suggested that these students hunt and fish a lot and pay attention to the weather and may amplify incorrect forecasts they experience. She further suggested that these students live in

flood zones and many have been cut off from evacuating by swift rising rivers.

A collective student model of physical and chemical processes is generally poor based upon interview and questionnaire data. The teachers indicated that some of the topics were skipped due to lack of time or they planned to cover later. The Likert-type scale items number 22, 24, 25, and 26 (Table 2) on the questionnaire give more positive results in terms of students physical and chemical understandings of the Gulf. The responses to these items indicate students recognize; (a) the Mississippi River as the major source of freshwater in the Gulf, (b) water can stratify based upon salinity and temperature, (c) salt domes form over considerable time, and (d) the origin of the Gulf Stream is in the Gulf of Mexico.

The next major superordinate concept is "biological productivity." A majority (63%) of the total students, especially from Urban Magnet High (76%) and Suburban Magnet High (83%), recognizes plankton as being beneficial. Forty-two percent of the students included trophic structure (food chain) in their answers. Only a small percentage recognized that some plankton may be detrimental such as dinoflagellates that produce red tides or cause shellfish poisoning. Data suggest that the students in this study have a well-developed idea of food chains, webs, and possibly energy transfer in a marine ecosystem. However, the concept of estuarine dependence by fish and shellfish was less developed. Only one third of the students from Urban Magnet High and Small Town High used nursery utilization and reproduction to explain estuarine dependence. The large miscellaneous category had many tautological responses such as "an area of the Gulf where these species live."

From the interview data, students' understanding of the commercial seafood industry centered around the species themselves (eight species mentioned such as shrimp and oysters), economic concerns (18%), and health concerns (18%). Twenty-seven percent mentioned TEDs and 14% mentioned bycatch and net ban. From the questionnaire data 57% of the students knew what TEDs are. At this time the net ban issue was just developing as a response to the Florida net ban passed during the November 1994 elections in that state. This later became a high profile issue in Louisiana. While only 14% of the students mentioned a net ban at the time it was an emerging issue. It speaks highly of those students to recognize a forth coming issue. If students can forecast issues, this will have implications for teaching and the development of Gulf literacy.

Fifty-one percent of the students indicated they wanted to know more about marine life related to the Gulf and 21% wanted to know more about marine mammals. Thirty-eight percent of the students knew a manatee is a marine mammal and 21% knew it is an endangered species. Additionally 26% listed their vulnerability to boats. Marine mammals seem to captivate student interest.

From a Likert-type scale item (Table 2, No. 17) students disagree that there is no connection between habitat loss and fisheries production. The connection of these organisms to their environment is important to understanding the Gulf as a large marine ecosystem.

It appears that students have a well-developed idea of biological productivity in terms of traditional food chains, commercial fishing, and diversity of animals. However, concepts of life cycles and estuarine dependence are not well developed.

"Human impacts" is the last superordinate concept in the conceptual framework of Gulf literacy. Fifty-nine percent of the students responded that marine debris is harmful because it harms and kills animals (see Figure 15). Four of the top five concerns about the Gulf listed by students on the questionnaire relate to human impacts. They are pollution, erosion, marine debris, and overfishing (see Figure 16). From the interview data four of the five top concerns listed relate to human impacts. They are pollution, erosion, seafood, and debris. In the construction of concept maps, students used a wide range of concepts in the construction of their maps. These responses were categorized (see Table 6) and the top five were animals, pollution, oil and gas, marine mammals, (e) and fishing. Student maps range from poor to well developed (see Appendix F). Figure F4 is an example of an excellent map and Figure F19 is an example of a poorly developed map. The concept map data combined with questionnaire data and interview data suggest students have a good understanding of what human impacts are related to the Gulf. Six of the 23 students used "recreation" in the construction of their maps and of course this fits under this human impacts superordinate concept. None of the experts or the researchers considered recreational impacts to the Gulf. This may be an oversight or imply these people have do not relate recreation to human impacts because of experience. The area of human impacts probably represents the highest area of student interest. The students are concerned about coastal erosion and the consequences. They are concerned when animals get tangled up in or ingest marine debris. They are concerned about the quality of their environment and the effects of pollution. Forty-four percent of the students had a developed concept

of nonpoint source pollution. These are areas that students may directly experience and have connections.

Thinking, Feeling, and Acting

Gowin (1981, pp. 48 - 49) states that "a person's self-interest in educative events might well be described as the deliberate connection-making between thinking and feeling that leads to intentional human acting and that thinking and feeling are intensely personal matters." This is consistent with the direction of scientific literacy and Gulf literacy. The thinking involves an understanding of a set of concepts and propositions. If personal relevant experiences can be attached to this framework of understanding, a student may be motivated to be self-actuating in terms of acting on a problem. A problem in this case may be a knowledge deficit or actual environmental problem. Personal relevant meaningful experiences are key to such problem solving.

Concept Mapping

Concept maps have great utility for both research and teaching. Each concept map constructed represents an idiosyncratic framework that allows researchers to get an approximation of that particular student's notions or concepts related to a superordinate concept. Construction of a concept map under a superordinate concept can be both evocative and generative. The superordinate concept is the key to a whole array of information and has a powerful organizing effect (Mintzes, Markham, & Jones 1993).

In this case the superordinate concept human impacts was given to the student and he/she constructed a concept map under this term. Most students were able to provide several concepts quickly. If a student reached a block, they were asked to start arranging the concepts on the

markerboard. Generally, this evoked new concepts once a framework was apparent. Also, once the map was drawn by the researcher, changes and additions were made at the student's request. Some students struggled initially with providing concepts and organizing them. However, once a few elements were in place they were able to quickly provide other elements and complete their map. In fact, most were quite proud of their map and surprised that they actually knew that much. The animation they demonstrated also came from a sense of accomplishment. This is something to consider in terms of building self-esteem in students. Evidence of the generative nature of concept mapping is provided by the addition of recreation as a human impact--ignored by the experts and author. Therefore, students were generating or constructing new knowledge based upon their experience.

Coconstruction of concept maps allowed the student to view and restructure their concept map. The student got to see their final product and leave with a greater sense of accomplishment. Similarly, the researcher felt more confident that he/she had a graphic representation that constituted a closer approximation of what the learner really knew about that topic (Wandersee & Abrams, 1993). While the teachers were not part of this process, their participation should be considered. During the process of interviewing and map construction none of the teachers expressed any interest in seeing the photographs of the maps. However, when they were shown the maps during a review of the results, they became very interested and inquisitive. Though they had used concept maps as part of the unit, they did not do actual construction, but made overheads of the concept maps provided in the booklet. It gave them a

chance to see their students in a new light. Two teachers, without solicitation, wanted to work with concept mapping again next year.

Implications

Curriculum and Instruction

We are at a time when the overwhelming volume of material that must be taught or covered in a school year needs to be pared down and, instead, taught more effectively (AAAS, 1989; Demastus & Wandersee, 1992). The phrase "less is more" is the rallying cry for this reform movement. Additionally, reform efforts stress integration of disciplines and thematic approaches to instruction and curriculum development. The selection of units that cross disciplines and have locally relevant issues such as Gulf literacy should be part of these reform efforts. Material that is inherently meaningful will have a greater chance at successful teaching and learning than vocabulary driven textbooks. This Gulf literacy project is an example of such a unit. Other units could be developed for other large ecosystems such as the Chesapeake Bay, Florida Bay, and the Everglades.

The development of such units could be accomplished by university educators and scientists, teams of teachers, and science supervisors over short periods of time such as a summer. A survey of the local papers and contacting a few experts could lead curriculum planners to the development of meaningful locally relevant material for instruction. Other educational enterprises could be asked to construct such materials. All the major aquaria and marine laboratories in the U.S. have education departments. Development of such materials could become part of their mission.

The teaching of difficult concepts such as "dead zones" perhaps could benefit from the use of concept mapping. There are a number of concepts necessary to the understanding of this concept. Concept mapping allows students to consciously make connections of these concepts to each other. While a student may understand most of the concepts necessary such as nutrients, phytoplankton, or dissolved oxygen, if they cannot use them to explain the phenomena of hypoxia then an understanding of a major concept necessary to understanding the Gulf of Mexico is not present. Particularly useful here would be the strategy of micromapping.

Micromapping is concept mapping where the student is supplied five terms or concepts. The student must construct a map with those terms and add five to seven more concepts or self generated examples. The key here would be what five terms the teacher chooses to supply--possibly terms he/she notices the students are not relating. In essence the teacher is making the students construct linkages between these concepts. One major advance of micromaps is their ease of evaluation. In a study on using concept mapping in a college course on evolution the instructor reported the average time spent on each map was five minutes (Trowbridge & Wandersee, 1994).

Research

Qualitative data are rich and often times voluminous and continuous that requires the researcher to choose a stopping point. This is necessary to present the research in a timely manner and reflect upon the data. This usually leads to the "what's next?" step. From here it would be beneficial to explore multidimensional literacy. Students could be tracked through the process of acquiring information on their own and what they do when presented with an environmental issue. An analysis of their conclusions

and solutions would be of interest. In this study they were asked to give time, which they stated they would give. When they were asked what law or regulation they would make related to the Gulf, students answered with heavy fines and penalties that models current governmental responses to environmental problems. How can more creative solutions be fostered?

The existence of critical junctures should be explored further. It is possible that linear vocabulary driven science courses or units do not reveal such pivotal points in instruction. As instructors try to integrate and teach material such as large ecosystems they may discover such junctures that are critical to holistic understandings. Methods for documenting the existence of critical junctures need further development. After analyzing the data, the researcher thought that there could be a possible correlation between the possible critical-juncture-concept dead zones, and related concepts such as plankton [$r(73) = .05, p < .05$], productivity [$r(44) = .05, p < .05$], and nonpoint source pollution [$r(39) = .28, p < .05$]. Though no correlation relationship existed based upon these selected questionnaire answers, this may be a possible method for examining related concepts.

Research regarding concept mapping should continue focusing on the construction of micromaps, generative nature of concept mapping, and coconstruction of concept maps.

Models of Literacy

Models are idealized representations of reality (the prototype) (Baretta-Berkker, Duursma, & Kuipers, 1992). When scientists attempt to explain natural phenomena it is through the use of a model--a deliberately simplified construct of nature (Pease & Bull, 1992). A model may be empirical and mathematical or it may be abstract. The Hardy-Weinberg

law of genetics is a mathematical model. Fisheries scientists must construct mathematical models of population dynamics before any management decisions can be made. Abstract models come in many forms such as verbal descriptions or conceptual frameworks. Darwin's description of natural selection is an example of a verbal model. In the classroom setting it is common to see models of various atoms and our planetary system hanging from the ceilings, far from reality, but a first attempt to create a concrete representation. Models have tremendous explanatory powers. Models allow a visual concrete representation. Models give insights to current world views--they are based upon current theories. Models may be predictive, such as climate models (at least the goal is prediction). The development of a model from its inception to current form allows the developer to understand the history and philosophy of science of that domain. For example, the development of models of the atom is a lesson in history and philosophy of science.

Scientific literacy and what it means theoretically and conceptually needs to be examined by the construction of frameworks such as Gulf literacy. Such frameworks allow instructors and researchers to operate within a local system of common concerns. The Gulf literacy framework would not have the same appeal to students and teachers in Nebraska. While large scale efforts such as Benchmarks for Scientific Literacy (AAAS, 1993) and National Research Council efforts to develop Standards are attempts to build a model of scientific literacy, there needs to be working microscale studies such as Gulf literacy. Such microscale studies have the benefit of grounding in reality and can be inherently meaningful due to the focus on local phenomena.

In terms of science education reform, the construction of curriculum materials that are science-based has much promise. These curriculum materials have the power to be generative in knowledge construction especially if accompanied by compelling graphics. The use of local relevant materials can provide a platform for learning about other scientific concepts and issues. With this approach the student learns to methodically seek new information to solve a knowledge gap or solve a problem. Here the goals of scientific literacy are closer to being realized.

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APPENDIX A
GOWIN'S VEE DIAGRAM OF THE RESEARCH

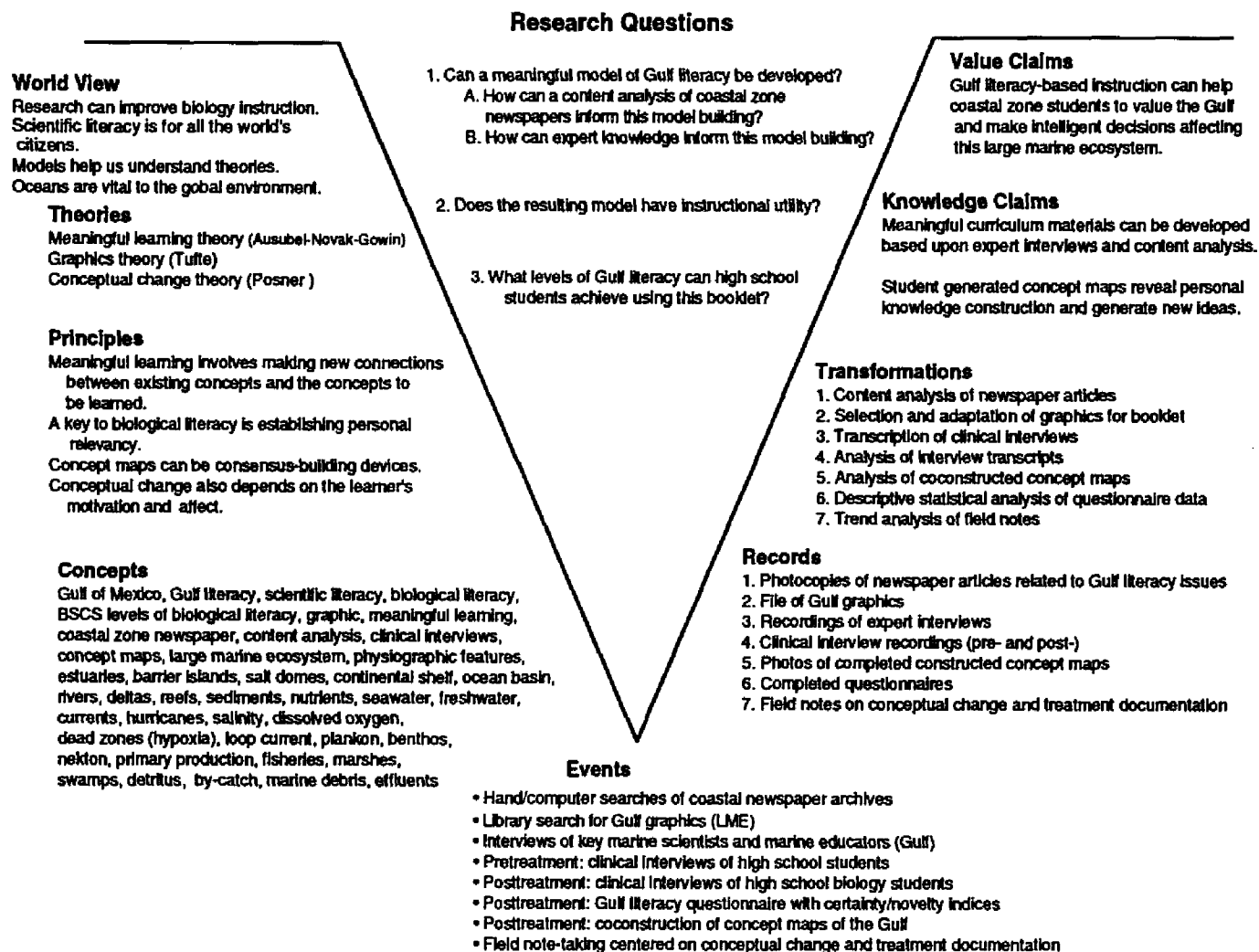


Figure A1. Gowin's vee diagram of the research.

APPENDIX B
GULF LITERACY BOOKLET

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GULF LITERACY

INTRODUCTION

The concept of Gulf literacy stems from current scientific literacy movements. Scientific literacy is the pervasive goal of science education reform. Other terminology associated with the scientific literacy movement is "science for all" (AAAS, 1989; BSCS, 1992). Definitions of scientific literacy vary, but there is agreement that a scientifically literate person should (a) understand key concepts and pervasive principles of science, (b) understand newspaper articles and graphics related to science issues, and (c) use scientific ways of evaluating evidence for individual and social purposes (AAAS, 1989; Demastes & Wandersee, 1992). With this in mind a marine science-based model of scientific literacy called "Gulf literacy" was constructed.

The Gulf of Mexico and its coastal environments are of great social, economic, and scientific importance. The Gulf of Mexico: (a) produces 40% of the nation's commercial fish yield, (b) it provides habitat for 75% of our migratory waterfowl, (c) has extensive coastal wetlands, (d) has 90% of US offshore oil and gas production, and (e) is where 45% of U.S. shipping tonnage passes through its ports. Major hard mineral resources such as phosphate, sulfur, and sand, underexploited fishery resources, large reserves of natural gas, access to freshwater for industry and rivers for commerce signal the continuing economic importance of this area. The present and future value of these resources, including the fact that 1/6 of the U.S. population lives in the coastal states of the Gulf of Mexico, place this great resource in jeopardy.



The Gulf is currently showing signs of stress by continued loss of habitat and wetlands, an increase in toxic discharges, oil spills, excessive nutrient loading, and increasing population. This is signaled by the closing of shellfish producing areas, marine debris, and the occurrence of red tides and dead zones (hypoxia). These problems cross county or parish, city, state, and national boundaries. It can be argued that an understanding of the Gulf of Mexico in terms of its history, ecology, natural resources, economic impact, and fragility should be part of the working knowledge of coastal zone citizens and part of K-12 science education.

The concepts and principles selected as a core for Gulf literacy were arrived at by content analysis of Gulf coast newspapers and from expert interviews. Newspapers from Corpus Christi, New

Orleans, Mobile, and Tampa were analyzed for articles related to the Gulf of Mexico. Since part of the definition of scientific literacy requires an understanding of what is in the newspaper, then it seems logical to examine newspapers. Newspaper articles may add personal relevance to scientific information which contributes to meaningful learning.

The selection of concepts was further supplemented with interviews of scientists and marine educators who are experts on the Gulf of Mexico. They were asked what they understand to be the most important concepts and principles in current environmental issues relative to the Gulf. Additionally, a search was conducted for compelling graphics to aid in the visual understanding of concepts

GULF LITERACY

INTRODUCTION

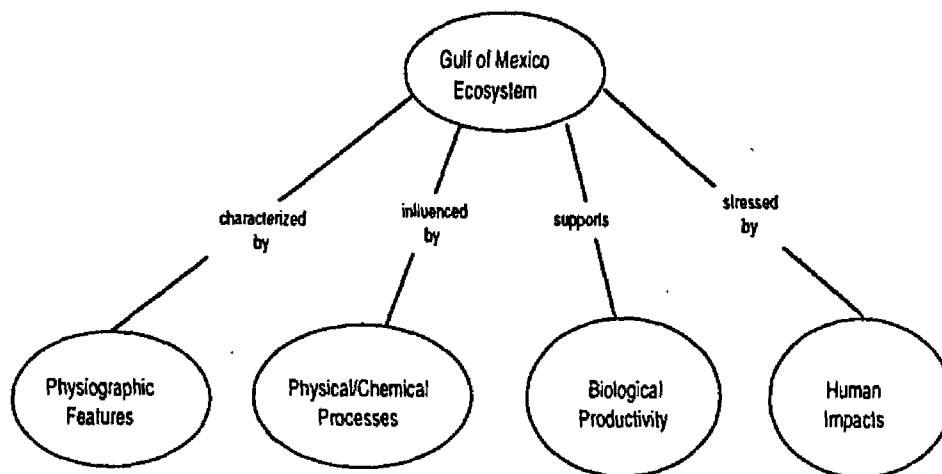
related to the Gulf of Mexico. Graphics capitalize on humans' visual learning capacities and foster visualization of scientific information. This is not meant to be a catalog or quantum of knowledge of all the environmental concerns associated with the Gulf of Mexico, but to establish some consensus of priorities and to select key marine education issues, particularly where scientific knowledge is vital to understanding the Gulf of Mexico as a large marine ecosystem.

The following pages contain concept maps that demonstrate the framework for this booklet and Gulf literacy. Concept maps are 2-dimensional representations of a set of concepts. The concepts are arranged in a hierarchy with a superordinate concept at the top. The concepts are linked by lines with connecting words that form the propositions uniting the concepts. There are cross links connected by dotted lines (by convention) which join branches of the map to create new propositions. A concept map should be anchored with examples, ideally they should be novel, mapper supplied, examples. The concept maps presented here were generated by the author based upon research as mentioned above and experience. It is a framework of understanding that allows the Gulf of Mexico to be viewed as a large marine ecosystem.

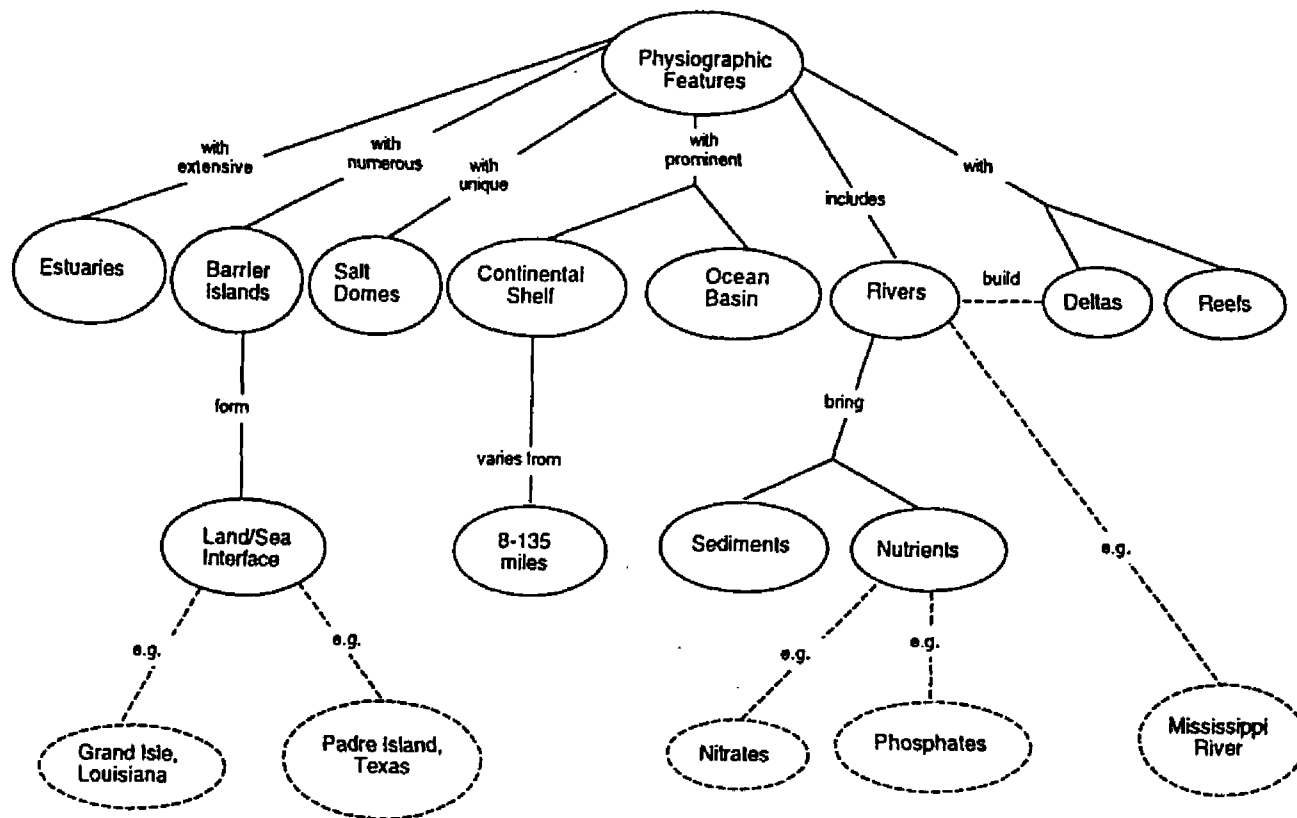
The individual lessons developed in this book each contain graphics that can be copied as an overhead transparency for classroom use. The primary graphic for each lesson will be on an odd or left hand facing page under the title of the topic. On the right hand facing page content information is provided, but is certainly not exhaustive. Key concepts are provided so that students and teachers can try to construct concept maps or at least make connections with other concepts, the lesson topic, and the Gulf of Mexico as a large marine ecosystem. A short class or take home activity is given to reinforce

and develop the concepts related to the Gulf. Most lesson topics have titles of newspaper articles related to that issue. This demonstrates a grounding of this topic as a real public concern. The lessons are organized around larger concepts and principles, but do not have to be followed in any particular order. The cross connectivity of concepts related to the Gulf of Mexico as a large marine ecosystem means a class will eventually get around to the other lessons despite their order.

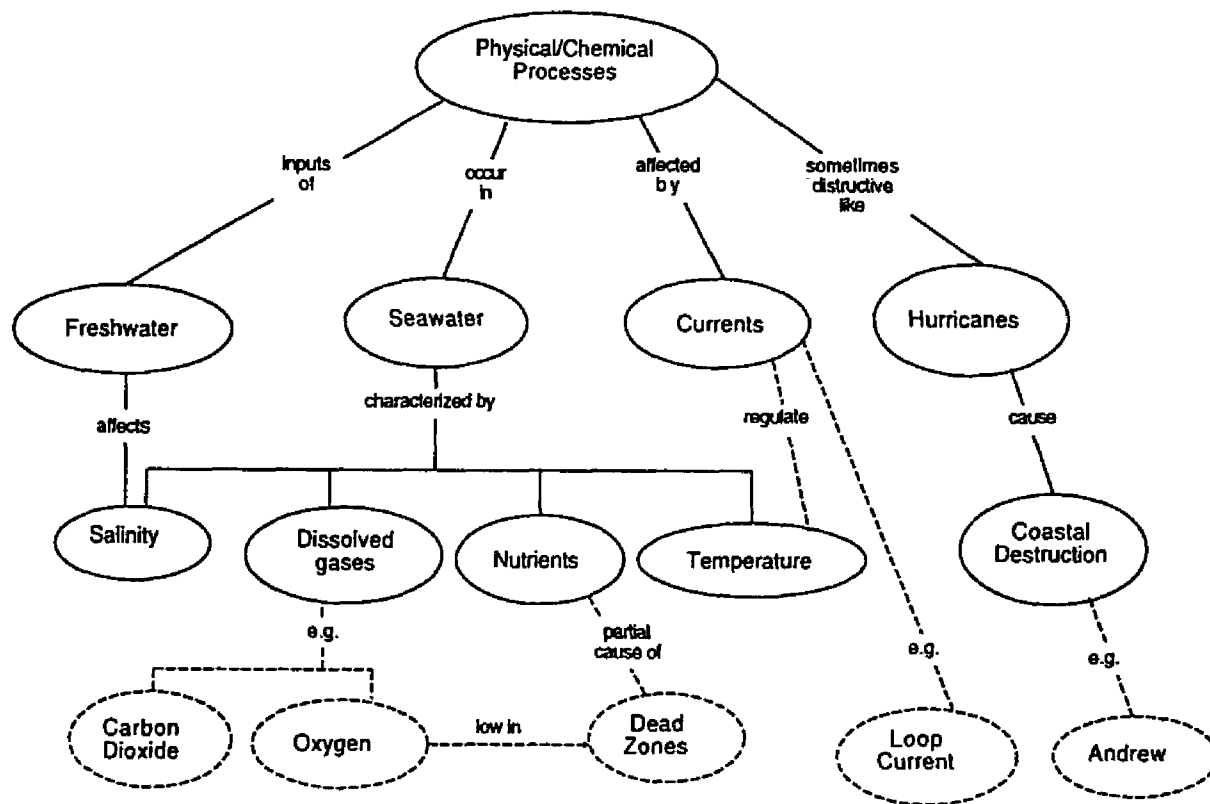
It is also important that students learn their role in the scheme of things related to the Gulf of Mexico. As with most shared and overexploited resources limits are found and choices must be made. Can a consensus be made by all user groups about the future use and exploitation of Gulf resources? What can an individual do as a citizen on the local and Gulf wide level? How can students and citizens express their concerns and seek answers to their questions? It is important for students and citizens to use scientific reasoning in their problem solving approach. The obtaining and evaluating of information before making a decision such as voting on land use rules, cleanup funds, or municipal treatment of sewage discharges are examples of citizen decision making. Hopefully the students will come to understand that we are all connected to the Gulf of Mexico.

CONCEPT MAPS**THE GULF OF MEXICO
A LARGE MARINE ECOSYSTEM**

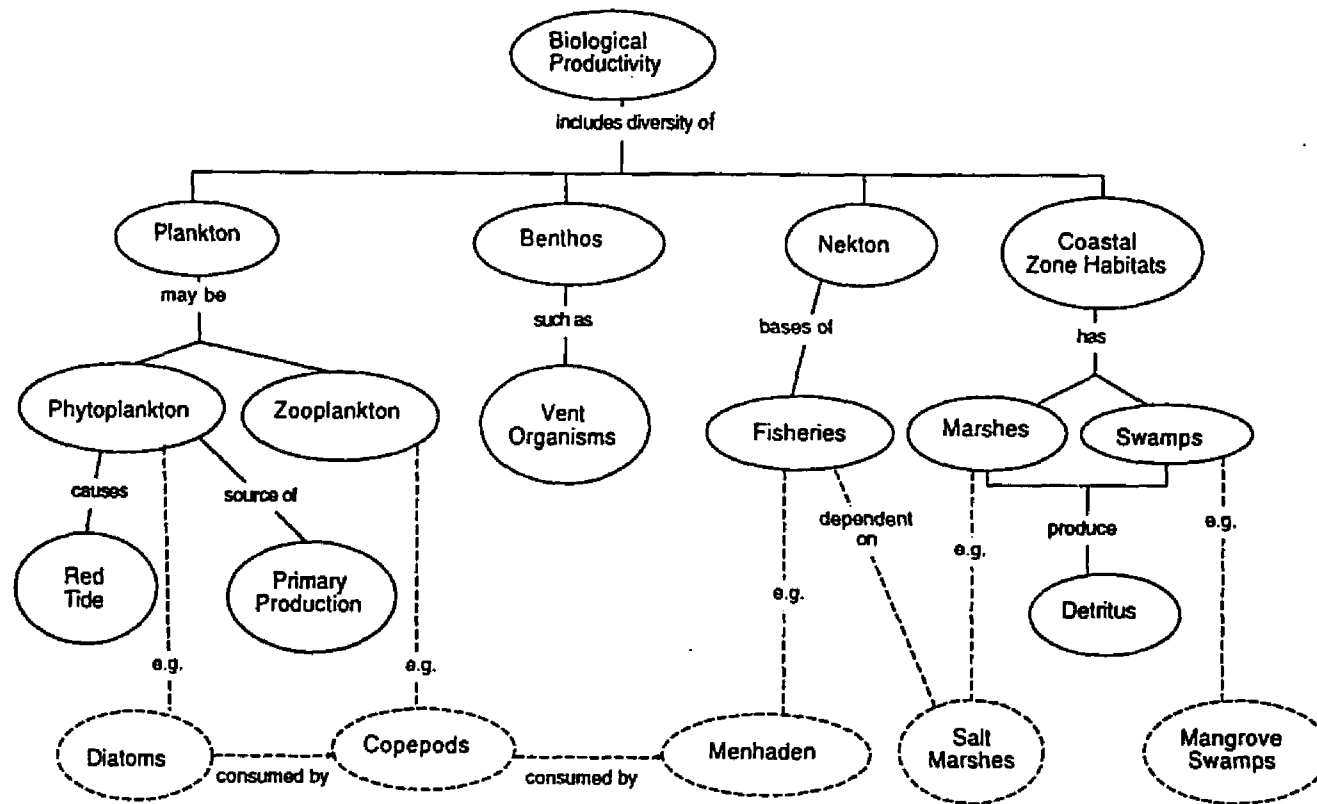
Concept map showing four conceptual organizers.



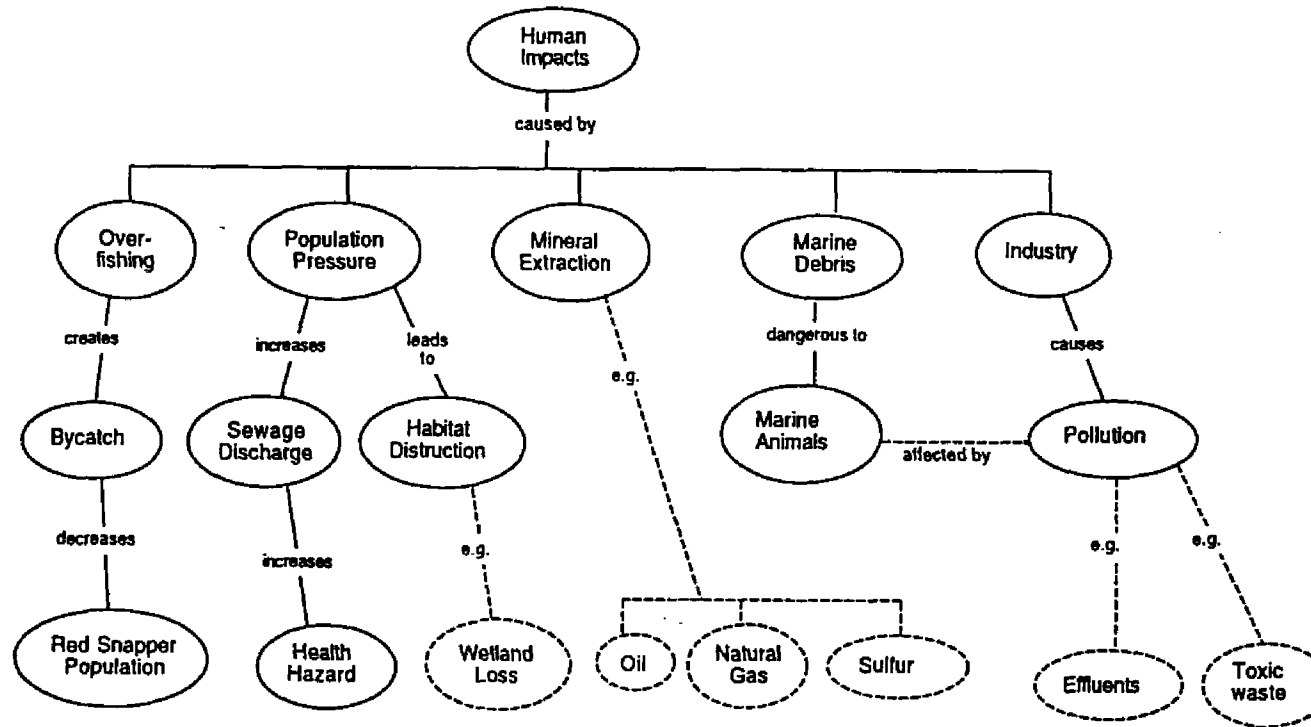
Concept map showing concepts related to physiographic features.



Concept map showing concepts related to physical and chemical processes.

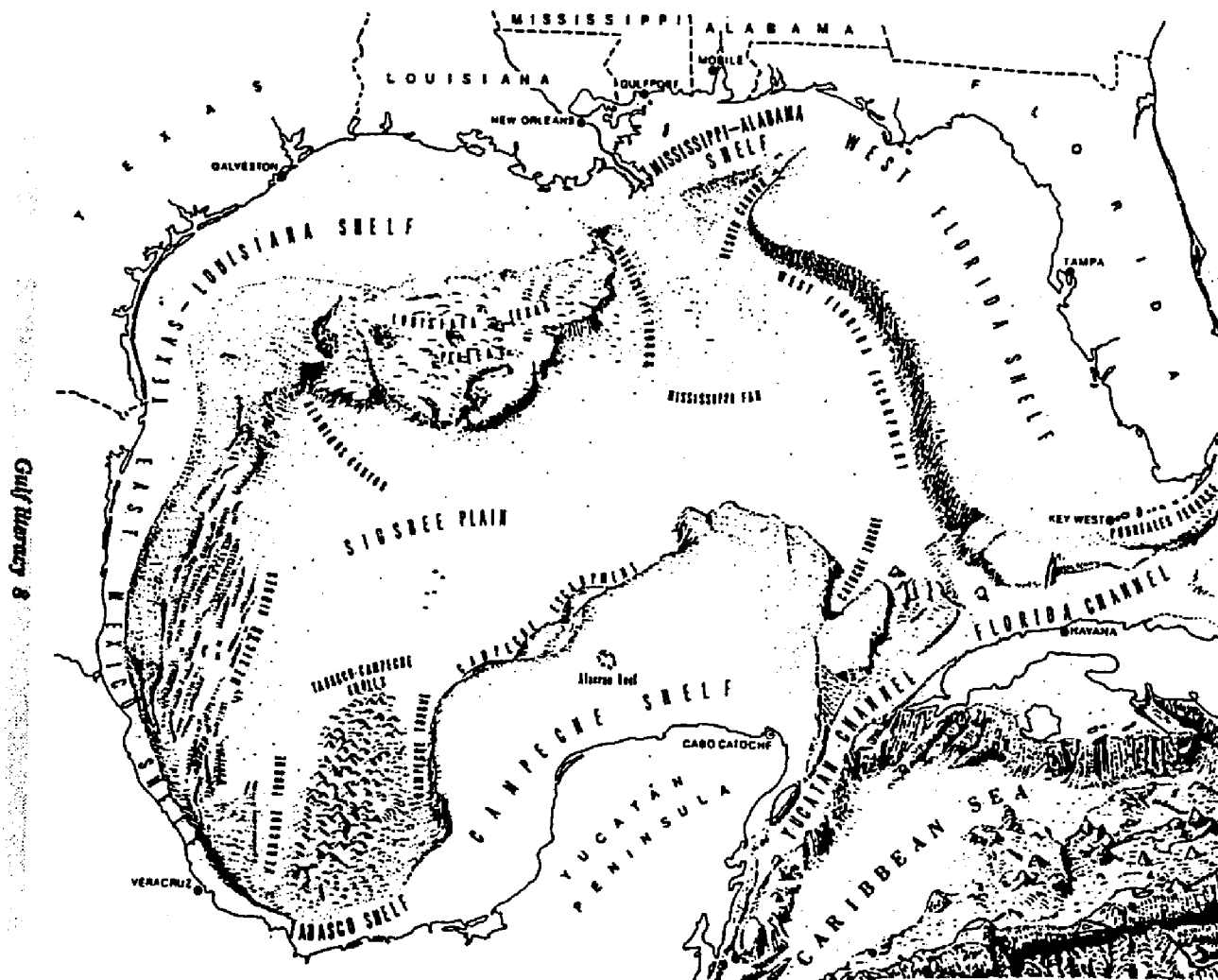


Concept map showing concepts related to biological productivity.



Concept map showing concepts related to human impacts.

PHYSIOGRAPHIC FEATURES OCEAN BASIN



Physiography of the Gulf of Mexico. Adapted from Gore (1992, endsheet)

PHYSIOGRAPHIC FEATURES

OCEAN BASIN

In the news

County endorses artificial reef rule

Tampa Tribune, Oct. 23, 1991

Gov. Hunt to dedicate fishing reef set to be built off Baldwin County

Mobile Register, Aug. 18, 1989

Concepts:

reef
barrier island
continental shelf
chemosynthesis

salt dome
worm rock
coastal plain
brine

The Gulf of Mexico is the 9th largest body of water in the world. When characterizing the ocean basin of the Gulf of Mexico, it is a mediterranean-type sea with several prominent features. It is semi-enclosed by land, oval in shape, connected to the Atlantic Ocean by the Florida Channel and Caribbean Sea by the Yucatan Channel. Other attributes of the Gulf of Mexico include freshwater input from rivers, coastal plains on the U.S. portion, barrier islands, bays, a broad continental shelf, submarine canyons, and a deep flat basin called the Sigsbee Plain. The average depth of the Gulf of Mexico is 5,000 feet and its deepest point is 12,598 feet located in the south-central portion called the Sigsbee Deep. The total area of the Gulf of Mexico is approximately 600,000 square miles. Off the Louisiana-Texas coast are salt domes rising 2,500 feet off the bottom capped with coral reefs. This area is known as the Flower Gardens. Other unique features include cold seeps where chemosynthetic bacteria support the fauna biologically similar to hydrothermal vents. In locations where salt domes have collapsed are hypersaline pools where beds of mussels exist.

The shoreline from the Yucatan Peninsula in Mexico to Cape Sable,

Florida in the U.S. is 3,600 miles. If you were to include all the bays, inlets, and tidal shoreline there is over 17,000 miles of coastline in the U.S. Gulf of Mexico. This coastline is diverse with sandy beaches, rocky coast, mangrove forests, and deltas.

There are several types of reefs in the Gulf of Mexico. The most familiar are coral reefs. The Gulf of Mexico does not support extensive reef formation like off the Florida keys, but some coral reefs appear off the Dry Tortugas, Vera Cruz, and the Yucatan Peninsula. The Flower Gardens are unique because they are formed on top of salt domes. They are also the northernmost living coral reef in the Gulf of Mexico. The Flower Garden reefs are located 110 miles south of Galveston in 60-100 feet of water. In the abundant estuaries, oysters form reef like structures with distinct ecological communities. Vermetid mollusks are snails with twisted worm like shells that settle and aggregate into reefs called "worm rock." These are found in Florida's waters. Sabellariid worms live in tubes of sand grains cemented together. Colonies of these worms forming reefs can be found in heavy surf zones of Mexican waters. Serpulid worms secrete tubes of calcium carbonate and colonies

PHYSIOGRAPHIC FEATURES OCEAN BASIN

form small patch reefs located near Baffin Bay, Texas and Vera Cruz, Mexico. At various places along the Gulf of Mexico rocky outcrops are reef-like and provide hard substrate for many invertebrates to settle. This structure also attracts fish resulting in a distinct ecological community. In some areas of Florida these rocky outcrops form sponge banks.

All the states along the U.S. Gulf of Mexico coast have an artificial reef program. It is designed to create fish havens for recreational fishermen and conservation of some species like the red snapper. Large structures like ships, railroad cars, material from torn down bridges, and oil platforms have been used. The presence of over 4,000 offshore oil platforms in the Gulf of Mexico greatly increases the area of hard substrate for fouling communities to develop. Fouling communities consist of barnacles, oysters, hydrozoans, bryozoans, sponges, and tunicates. Each rig or platform can be an artificial reef of sorts.

Activity

Build a model of the Gulf of Mexico

You will need:

chart of Gulf of Mexico with depths or soundings
carbon paper
card board or foam core
paper mache
blue paint
magic markers

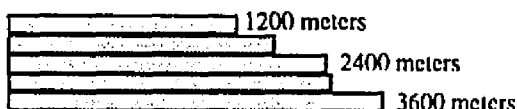
Directions:

Examine the contour intervals given on the chart and decide what depth each thickness of card board will represent

(e.g., 1 thickness of card board = 600 meters).

Place carbon paper (you may need to use several sheets) between a chart of the Gulf of Mexico¹ and a sheet of card board. Start with the deepest contour on the chart (3600 meters) and trace around it with a ball point pen. This is your first piece to glue on a bottom piece when you finish cutting it out.

To continue trace the next contour and cut out the center part. Place the cardboard over the bottom piece. Repeat this until you reach land. The last piece of board should be land.



Optional: With paper mache smooth out the features like the continental slope and squared off edges created by the cardboard. Paint the ocean blue. When dry, label various parts such as continental shelf, continental slope, and ocean basin.

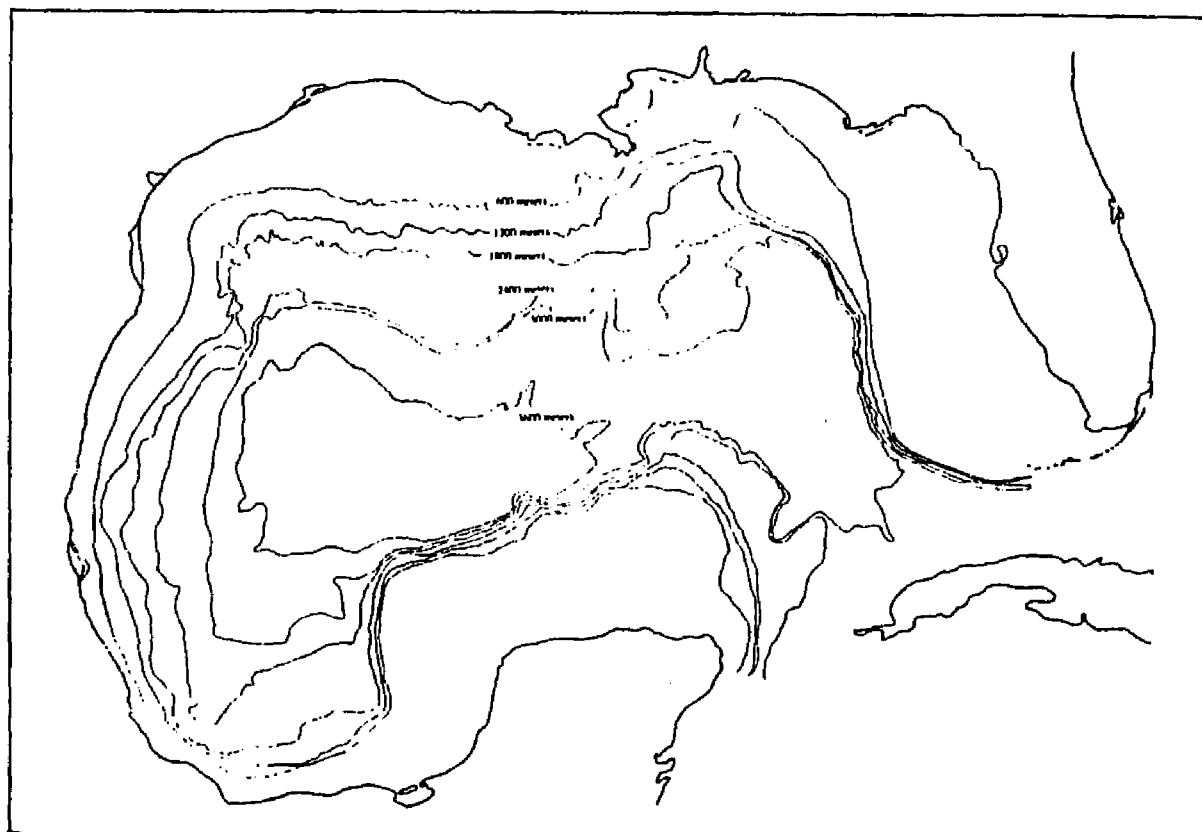
With a magic marker draw in the major rivers on the land.

You may wish to continue with the contours on land demonstrating coastal plains, etc. You may also wish to paint the land using green or brown paint where appropriate.

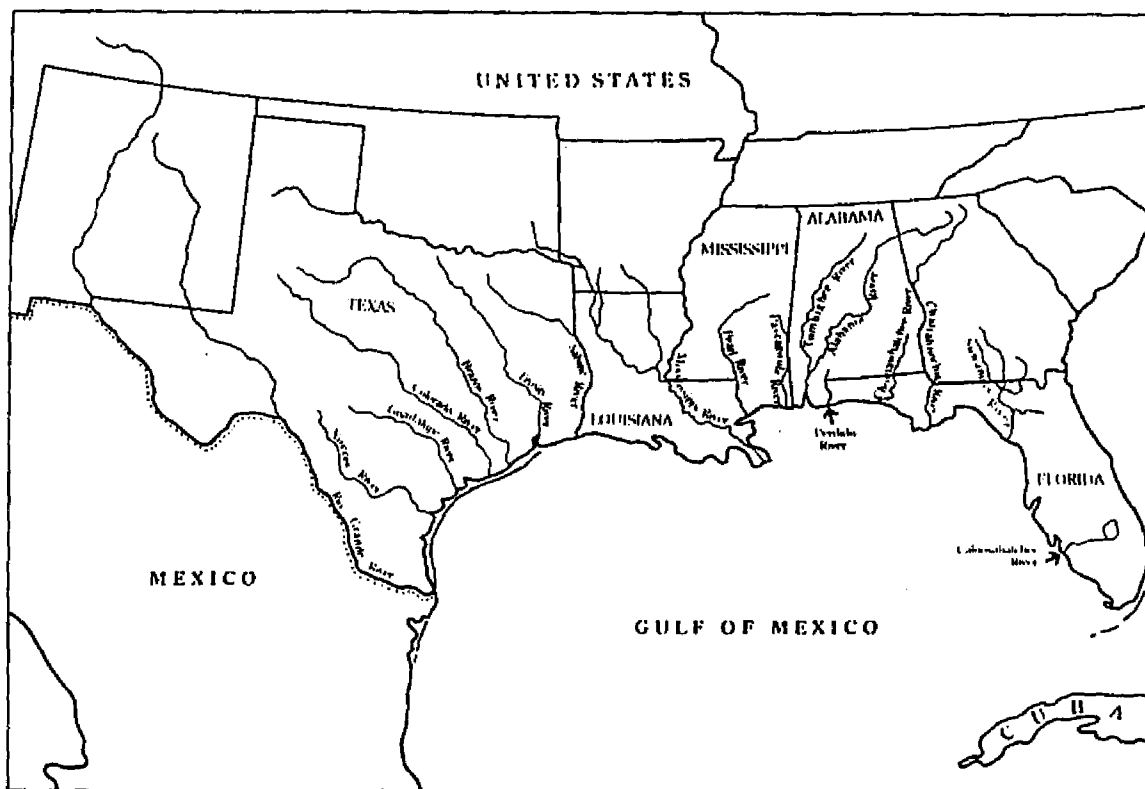
1 - An 8x10 bathymetric map is provided with this exercise. You may wish to have this enlarged several times. You can purchase a nautical chart of the Gulf of Mexico which is 36 x 48 inches for approximately \$15.00 from most map stores.

PHYSIOGRAPHIC FEATURES

OCEAN BASIN



Bathymetry of the Gulf of Mexico. Isobars (contour lines) are in units of 600 meters.

PHYSIOGRAPHIC FEATURES**RIVER INPUT**

Major rivers that flow into the Gulf of Mexico.
Used by permission from the Center for Marine Conservation (Maraniss, 1991)

PHYSIOGRAPHIC FEATURES

RIVER INPUT

In the news

Dead fish line Nueces River near bay
Corpus Christi Caller. Sept. 02, 1988

Scientists to track Manatee River pollution
Tampa Tribune, June 20, 1992

Concepts:

sediment
nutrients
pollutants
phytoplankton

estuary
deltas
salinity
primary productivity

There are 44 major rivers that empty into the U.S. Gulf of Mexico. It is the influence of these rivers on the broad continental shelf and creation of estuaries that contribute to the rich fishery resources of the Gulf. Rivers bring many things to Gulf other than freshwater. Sediment, nutrients, pollutants, and debris are brought to the Gulf via rivers. The Mississippi River is by far the largest contributor of all of the above. It is a major river system draining 40% of the contiguous U.S. and part of Canada (1,250,000 square miles of land). Annual water input averages 724 billion cubic feet. This would completely fill an empty Gulf in 12.5 years (Leonold and Davis, 1966, p. 92).

Freshwater inflow into bays and lagoons creates estuaries. Estuaries are highly productive and 95% of commercial species of fish and shellfish are estuarine dependent. These animals utilize the estuary during their life cycle usually during larval and juvenile stages. The quality of the freshwater inflow affects the environmental quality of the estuary which may impact the organisms within the estuary. Many oyster beds within estuaries are closed to harvesting because of pollutants in the water.

The channelization of freshwater inflow threatens estuaries. The creation of channels and canals reduces water flow to estuaries and reduces the amount of time water spends in an estuary thus reducing sediment deposition and availability of nutrients. The reduced flow into an estuary will cause salinities to rise which can stress plants and animals that may have no or little tolerance to saltwater. Reduced flow means less sediment which is needed for marsh and barrier island accretion and maintenance. In two locations in Louisiana, freshwater is being diverted from the Mississippi River into high salinity areas to maintain estuarine conditions. As demand for freshwater increases upstream, the potential for alteration of freshwater inflow increases. This condition may alter estuarine habitat and the biological productivity of Gulf waters.

Heavy sediment deposition from rivers may result in delta formation as apparent in the Mississippi River Delta and Atchafalaya River Delta. Also, the amount of suspended sediment affects how far light can penetrate in coastal waters, which becomes a factor in phytoplankton growth. Not visible, but certainly very important, are terrestrial derived nutrients in coastal and shelf waters. Nitrates, phosphates, and silicates

PHYSIOGRAPHIC FEATURES

RIVER INPUT

are all important for phytoplankton growth (primary productivity). Therefore, these nutrients enrich coastal waters making them more productive than they would be otherwise. At certain times of the year a large amount of nutrients are received from the Mississippi River because of spring flooding, industrial discharge, and agriculture practices. This may lead to a phytoplankton bloom. A bloom is a population explosion of the phytoplankton with a large increase in numbers and biomass. This bloom combined with density barriers created by differences in salinity and temperature can cause red tides and hypoxic zones in the Gulf (see section on hypoxia).

It is important to understand that freshwater inflow is not constant or smoothly distributed around the Gulf. River discharges are usually peak during the late spring, but unusual weather conditions in the interior of the U.S. may alter peak discharge in amount of water and time of peak. Tidal effects and wind direction can also influence salinity in estuaries. The graph on the next page shows that the majority of Gulf discharge is around the Mississippi and Atchafalaya Rivers.

Rivers are the conduit to the interior portion of the U.S. River borne transportation historically and presently moves tons of raw and manufactured materials such as wheat and oil up and down stream. Many interior cities are vitally linked to the Gulf of Mexico.

Rivers with drainage area over 1000 square miles:

- Rio Grande (TX)
- Nueces River (TX)
- San Antonio River (TX)
- Guadalupe River (TX)
- Colorado River (TX)
- Brazos (TX)
- Trinity River (TX)
- Neches River (TX)
- Sabine River (TX-LA)

- Calcasieu River (LA)
- Atchafalaya (LA)
- Mississippi River (LA)
- Bogue Chitto (LA)
- Pearl River (LA-MS)
- Pascagoula River (MS)
- Tombigbee River (AL)
- Alabama River (AL)
- Escambia River (FL)
- Choctawhatchee River (FL)
- Aplachicola River (FL)
- Ochlockonee River (FL)
- Suwannee River (FL)
- Withlacoochee River (FL)
- Peace River (FL)

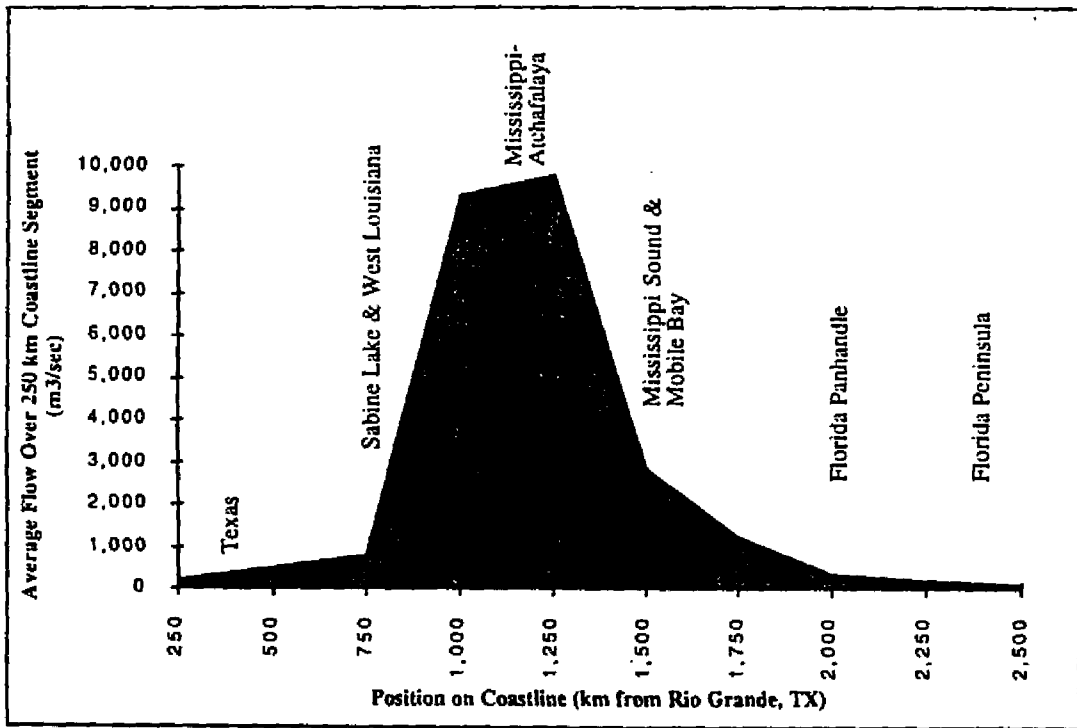
Activity

Where does all the water go?

If the Gulf of Mexico can be filled in 12.5 years just from the Mississippi River alone, where does the water go? Why doesn't the Gulf overflow its banks?

Where are large reservoirs of water? of freshwater?

Is it possible for water from Iowa to find its way to Florida? Why or Why not?



General Variation of River Flow

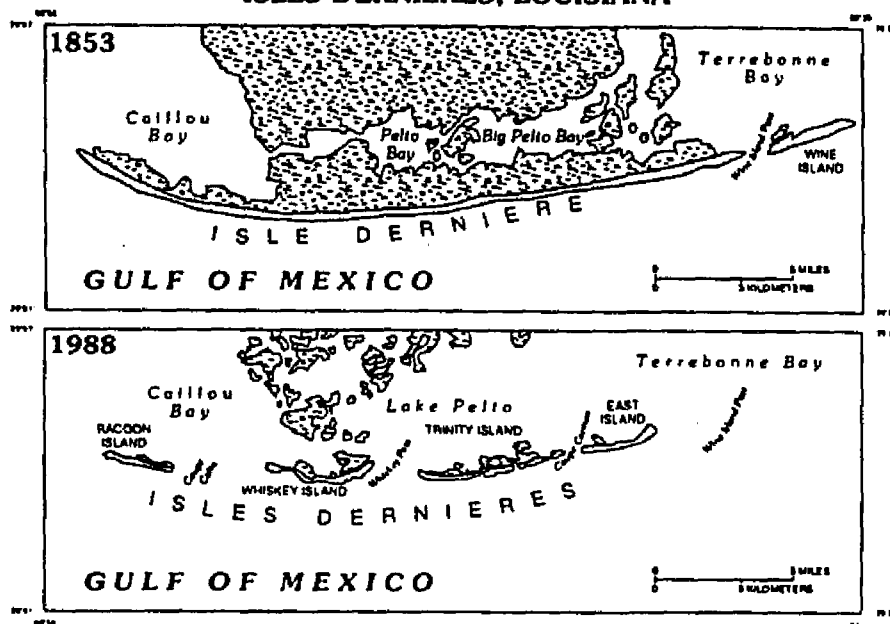
RIVER INPUT

PHYSIOGRAPHIC FEATURES

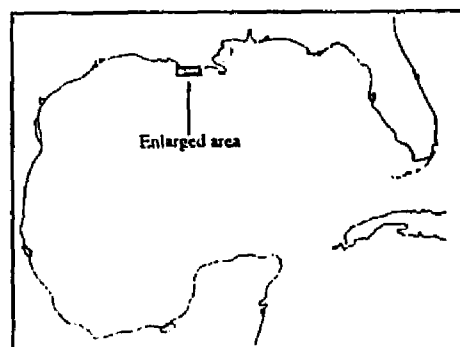
PHYSIOGRAPHIC FEATURES

BARRIER ISLANDS

HISTORICAL SHORELINE CHANGES ISLES DERNIERES, LOUISIANA



Courtesy of Louisiana Geological Survey



PHYSIOGRAPHIC FEATURES

BARRIER ISLANDS

In the news

Residents of rustic barrier island fight proposal for development

Tampa Tribune, Apr. 08, 1990

Gulf keeps swallowing Grand Isle

Times Picayune, May 1, 1991

Concepts:

barrier island
storms
development
estuaries
dunes

communities
saltwater
nutrients
habitat
sediment

Barrier islands along the Gulf of Mexico are summertime family playgrounds. The white sands, warm blue water, and gentle surf make the beaches of these islands premier tourist attractions. Recreational activities include swimming, fishing, boating, shell collecting, and just relaxing on the beach. Many of these beaches are highly developed giving them the appearance of small cities with condominiums and hotels creating a skyline against the Gulf of Mexico. However, beaches can be found in a natural undeveloped state at various national and state parks along the Gulf. We are fortunate to have many barrier islands incorporated into the National Seashore System operated by the National Parks Service.

Despite their tourist appeal barrier islands have important functions. One function of barrier islands is that they are the first line of defense from storms. The islands take the brunt of storm in terms of wave attack. They act as barriers to the ocean preventing saltwater from intruding further inland. Also, they act as retaining structures keeping freshwater loaded with nutrients and sediment from completely spilling into the ocean. In essence, they maintain the integrity of the estuaries behind them. They are the nesting sites

for many shorebirds such as terns and resting places for migratory birds such as gulls. Endangered seaturtles use islands and beaches as nesting sites including the most imperiled, Kemp's Ridley sea turtle.

Barrier islands are very desert like in terms of habitat. There are few trees so there is little shade. The strong sun and reflection by the sand create high surface temperatures. Sand is very porous and water drains through it very quickly. Therefore, when it does rain water drains through the soil very quickly. Plants that colonize barrier islands adapt to heat and water shortages in the same way desert plants do by succulence, reduced stomata, and shallow root systems. Animals adapt by being nocturnal or getting their water from the plants they eat.

Distinct zones are recognized on barrier islands. The surf zone which may be physically brutal, is occupied by diatoms on the surface. Between the sand grains (interstitial species) there are amphipods, mole crabs, marine worms, mud shrimp, and colorful coquina clams. Moving up the beach on to the berm, ghost crabs and their burrows are obvious. Here is where drift lines left by previous high tides are found. The dunes provide enough elevation to protect plants

PHYSIOGRAPHIC FEATURES

BARRIER ISLANDS

from most tides and pioneer plants such as grasses and vines are found. Behind the dunes there is more protection from the saltwater and salt laden wind spray. Low moist areas called swales are found there. If the island is wide enough, thickets of salt tolerant shrubs of Yaupon and Myrtles are found grading into maritime forest. The sound or bay side of barrier islands is dominated by salt marshes and mangroves.

Barrier islands may be some of the most valuable real estate along the Gulf, but are the least stable. Barrier islands are essentially a large ridge of sand or a sand dune. The action of the wind, waves, and currents transports the sand generally in the direction of prevailing winds and currents. When transport rates are high and sources of new material are cut off, the island becomes lower and lower to the point where it can no longer support vegetation and becomes submerged. Submerged relict barrier islands are found on maps labeled as shoals. Human activities such as removing dunes and plants for development, building jetties and seawalls, and vehicle traffic all reduce the island's natural sand supply and ability to maintain itself. Dunes are essentially reservoirs of sand and plants hold the sand in place. Most modern building codes prevent the distraction of dunes, but for many years dunes were leveled for progress.

Principle barrier islands of the Northern Gulf are:

Padre Island (TX)
Mustang Island (TX)
Matagora (TX)
Galveston Island (TX)
Marsh Island (LA)
Isle Dernieres (LA)
Timbalier Islands (LA)
Grand Isle (LA)
Grand Terre Island (LA)
Chandeleur Islands (LA)
Cat Island (MS)
Ship Island (MS)

Horn Island (MS)
Dauphin Island (AL)
Perdido Key (AL)
Santa Rosa Island (FL)
Cape San Blas (FL)
St. George Island (FL)
Dog Island (FL)
Treasure Island (FL)
Anna Maria Island (FL)
Longboat Key (FL)
Siesta Key (FL)
Casey Key (FL)
Gasparilla Island (FL)
Estero Island (FL)
Captiva Island (FL)
Sanibel Island (FL)
Ten Thousand Islands (FL)

Activity:

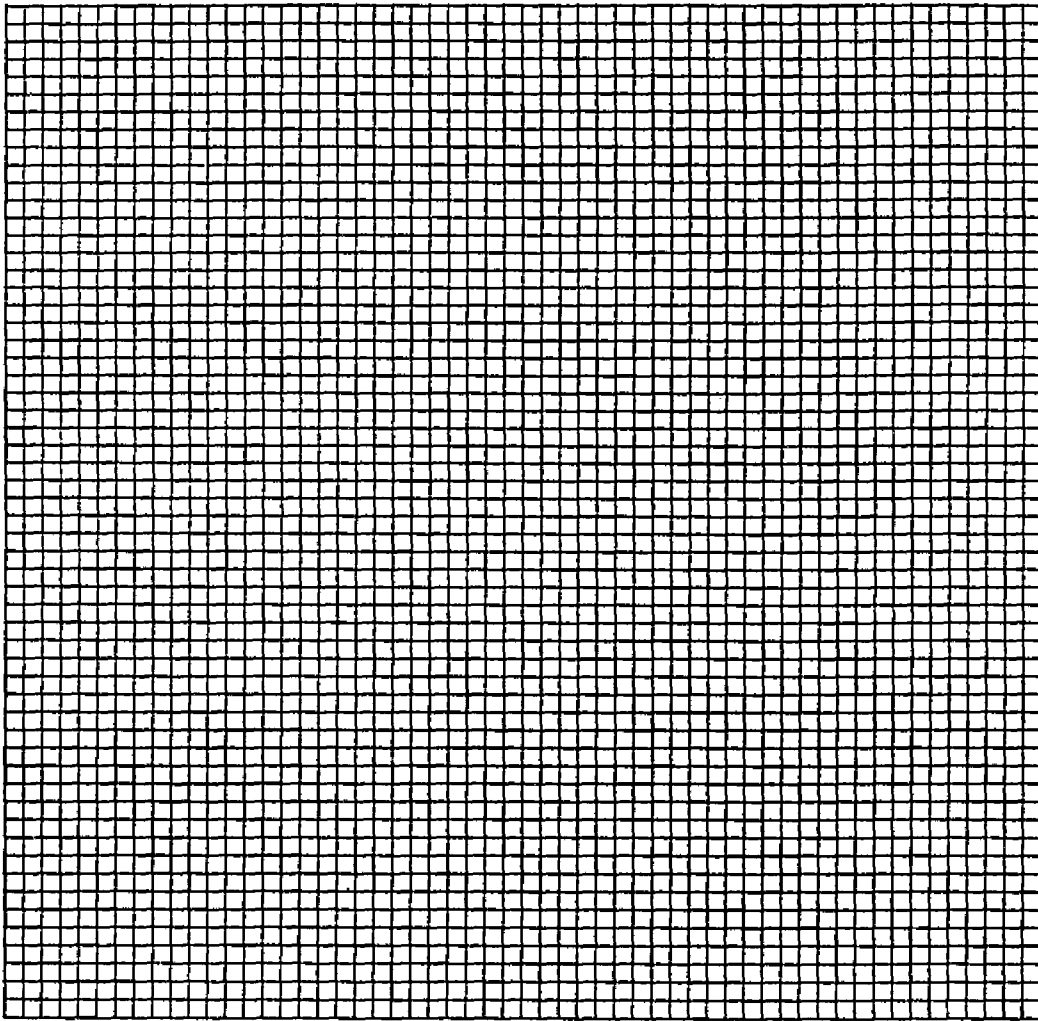
Determine land loss

Determine the land loss and the rate of land loss for Isle Dernieres, Louisiana. (Also called Last Island).

Place a transparency copy of the graph paper over the maps of Isle Dernieres 1853 and 1988. Each square represents 1 square kilometer. Count the number of squares on the graph paper that include or touch land for each map. Subtract the number obtained from the 1853 map from the number counted on the 1988 map. This is your total land loss over 155 years.

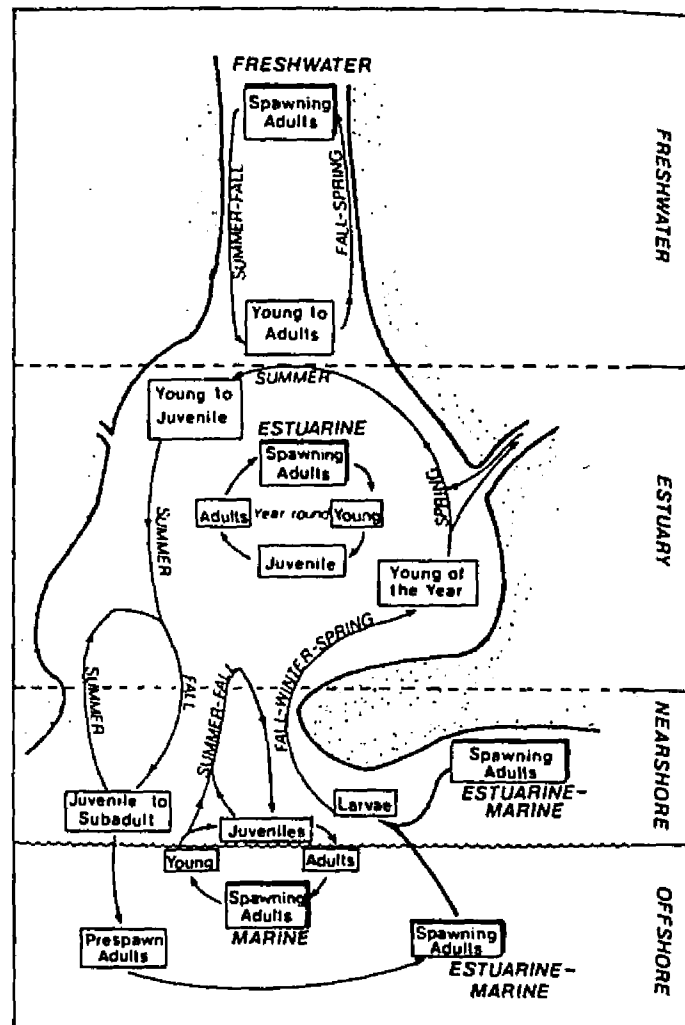
What would be the rate of loss for 20 years (a generation)?

Predict when the island will be totally gone.

PHYSIOGRAPHIC FEATURES**BARRIER ISLANDS**

PHYSIOGRAPHIC FEATURES

ESTUARIES



Temporal and spatial use of estuaries. Adapted from Day (1989, p. 402)

PHYSIOGRAPHIC FEATURES

ESTUARIES

Estuaries In the news

Dramatic decline noted in birds of Mobile Bay
Mobile Register, Dec. 19, 1993

Tampa Bay is in line for cleanup
Tampa Tribune, Apr. 19, 1990

Concepts:

estuary
phytoplankton
euryhaline
nutrients
adaptation

primary productivity
substrate
detritus
dissolve organic carbon (DOC)
tolerance

Estuaries are semi-enclosed bodies of water with free connection to the ocean in which seawater is diluted by freshwater from upland sources. It may be simpler to say estuaries are where freshwater and saltwater mix. This is the area of water that is found in the bays, sounds, lagoons, and tidal creeks of the Gulf of Mexico. Estuaries are a transition zone between freshwater and marine ecosystems. It is an area of physical mixing and chemical reactions. Estuaries are high in biological productivity and are important nursery areas for fish and shellfish.

The biological productivity of estuaries is higher than any farming practiced on land. Net primary production in an estuary is comparable to coral reefs and tropical rain forests. Primary production is the storage of energy as an available food source through photosynthesis or chemosynthesis. There are several sources of primary productivity in estuaries: (a) phytoplankton in the water column, (b) benthic diatoms on the substrate or bottom, (c) marsh grasses, (d) aquatic grasses, and (e) mangroves.

The Gulf is experiencing tremendous loss of marshes and seagrass beds (see habitat degradation). The loss of marshes

and seagrass beds means less primary production in the estuary and hence less secondary and tertiary production--available energy (food or biomass) at the next higher step in the trophic structure -- which may be commercially important species of fish and shellfish.

Since the surrounding marshes found in estuaries are made up primarily of grasses, they form the basis of a detrital mill. Marsh grasses like *Spartina* are annuals and die off every year. The dead plant material undergoes a decay process where it is broken down continually into smaller pieces. As part of this decay process, the bits of plant material become covered or enriched with bacteria and algae adding to the nutritional value of the detritus. Detritus is an additional food source found in estuaries along with the primary producers thus increasing potential for productivity. This combined with an input of nutrients and dissolved organic carbon (DOC) from land drainage further adds to the productivity of these areas. Poorly understood is the role of microbes such as bacteria, cyanobacteria, and viruses in estuarine productivity.

Besides their role in primary production and detrital production, marsh plants have other functions. These plants

PHYSIOGRAPHIC FEATURES

ESTUARIES

slow the flow of water through an estuary thus trapping sediment and slowing sediment transport. This allows nutrient enriched water to have a longer residence time in the estuary, slowing the freshwater advance to the Gulf. The roots of marsh plants also hold the sediment in place. Plant litter also contributes organic matter to marsh soil. Marsh plants offer storm protection by absorbing wave and wind energy before reaching the mainland.

Since there is an abundance of food at primary and secondary trophic levels, 95% of the commercially important species of fish and shellfish such as shrimp, menhaden, and drums spend part of their life cycle in the estuary. Generally it is the larval and juvenile stages. There is plenty of available food and protection in the marsh grasses and dark muddy waters. At high tides organisms can utilize marsh surfaces for foraging and additional protection.

The estuarine habitat is partitioned by time and space. Different organisms, especially fish, will occupy the estuary during different times of year to maximize a food source or to avoid competition (see table). Predator avoidance and physiological tolerances to fresh and saltwater will affect where certain organisms will be found within an estuarine system. Estuaries and the marshes they surround are also the habitat for terrestrial animals such as raccoon, nutria, terrapins and other turtles, resident birds, and migratory birds.

Estuaries with its associated marshes and islands is critical habitat to many species of birds such as waterfowl, wading birds, and marine birds. Fortunately, large wildlife refuges have been established along the Gulf states. The Aransas Wildlife Refuge in Texas is notorious for its winter-time whooping crane population. Other endangered species of birds that utilize estuarine habitat along the Gulf include bald eagles

and brown pelicans. Estuaries can be seen as ecosystems with many associated communities such as salt marshes, soft bottom communities, and oyster reefs. Oysters are discussed as a separate section under biological productivity.

Estuaries are considered to be physically dominated systems. That means it is the physical factors of salinity, temperature, turbidity, sediment, currents, tides, and winds that determine what organisms live there. Organisms that occupy an estuary usually have high tolerances or special adaptations to deal with wide fluctuations in physical conditions. Many species minimize the physiological stresses by being a temporary resident in the estuary and moving out during times of stress.

There is physical mixing of saltwater and freshwater occurring in the estuaries which means that the salinities in estuaries are lower than ocean water. The salinity varies depending on tidal conditions, wind conditions, and rainfall in the drainage basin. For plants and animals that live within estuaries they must have tolerances or adaptations for dealing with a wide range of salinities. This is known as euryhaline. Because of the influx of different water masses and the fact that estuaries are shallow, temperatures vary widely within estuaries requiring further tolerances or adaptations. Wide ranges in temperature and nutrient input with possible eutrophication make oxygen levels vary in estuaries. This adds to the other possible physiological stresses an organism may encounter.

The Environmental Protection Agency (EPA) has designated large estuarine areas along the Gulf coast to be part of the National Estuary Program. This designation is for the purpose of resolving conflicting uses, restoration, conservation, and planning related to those estuarine areas. The National

PHYSIOGRAPHIC FEATURES

ESTUARIES

Estuary Program areas in the Gulf are: Galveston Bay Estuary, TX; Corpus Christi, TX; Terrebonne-Barataria Estuary, LA; Sarasota, FL; and Tampa Bay Estuary, FL. The National Oceanic and Atmospheric Administration (NOAA) operates a program called the National Estuarine Research Reserve System (NERRS). The goal of this program is to acquire a system of estuaries that will serve as natural field laboratories. There are currently three such reserves in the Gulf of Mexico: Weeks Bay, AL; Apalachicola, FL; and Rookery Bay, FL.

What different concerns would each of these areas have? What are their common concerns? Think about people and natural resources.

Why is it important to reserve or set aside certain estuaries as natural laboratories for research as being done by NERRS?

On maps and charts estuaries are not labeled as such, but are identified by their geographical area. On state or Gulf of Mexico maps locate areas that you think are estuaries. Why?

Activity

Where are the estuaries?

On a map of the Gulf of Mexico locate the areas mentioned above as part of the National Estuary Program.

Salt and living cells

Slice a potato into 2 equal pieces.

Weigh each piece.

Soak one piece in freshwater and the other in saltwater.

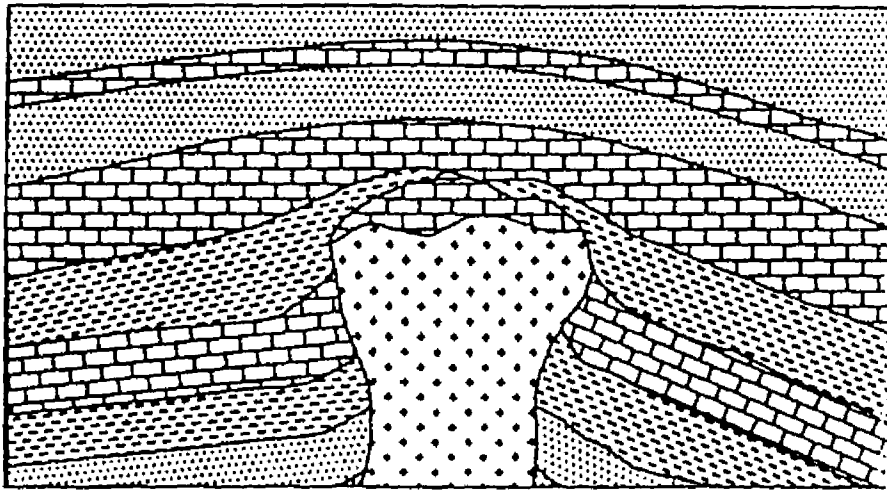
After 30 minutes weigh and feel each potato slice.

What happened?

What happens to animals and plants when exposed to water of different salinities?

Temporal separation by fish in an estuary

Name	Peak occurrence in the estuary by month											
Spot				X								
Croaker				X								
Red drum									X			
Star drum								X				
Bay whiff						X						
S. flounder			X									
Lined sole							X					
Menhaden				X								
Anchovy									X			
Mullet				X								
Month	J	F	M	A	M	J	J	A	S	O	N	D

PHYSIOGRAPHIC FEATURES**SALT DOMES****Salt Dome****Key****SALT****SANDSTONE****LIMESTONE****SHALE**

PHYSIOGRAPHIC FEATURES

SALT DOMES

In the news

Report: Petroleum Reserve neglects safety
Times Picayune, June 7, 1992

Miss. salt dome may house oil
Times Picayune, March 7, 1992

Concepts:
salt dome
sedimentation
hydrocarbons

brine
groundwater
diapirs

A geological feature of the Gulf of Mexico is the presence of salt domes. They represent a key to the history and physical and chemical processes taking place within the earth's crust of the Gulf of Mexico. During the origins of the Gulf basin 250 million years ago there was a separation of continental plates (the break up of Pangaea and a shallow sea was formed. The sea filled with water from land runoff and from a partial connection to the proto-Atlantic Ocean over a shallow sill. The intense heat of the Jurassic period 150 million years ago caused water of the Gulf to evaporate at a high rate. The upper layers of water became saltier because of the loss of freshwater through evaporation becoming a brine. These briny waters were denser than the underlying water and sank, forming a thick salt layer on the ocean floor. This layer of salt is called Louann salt named for the Arkansas where it was discovered.

Later glacial activities and river formation caused tons of sediments to cover this salt layer several miles thick. This continued sedimentation process produced a tremendous weight on top of the salt. The salt rock does not compress and is relatively light. The sedimentation process created sandstones, siltstones, and shales which are all heavier or more dense than the salt rock. The tremendous overlaying pressure liquefied the salt layer

and it flowed upward like a large bubble, mushroom, or pillar much in the same manner as observed in a lava lamp. The bubble like intrusions are called diapirs and the process is called diapirism. The result was columns of salt rising towards the surface. The rate of salt dome formation is .1 to one millimeter per year for several million years with intervals of dormancy. When they reach the surface they form a dome like structure 2 or more miles across. Many salt domes of the Gulf would be higher than Mount Everest if they were above ground. Some salt domes may reach eight miles above the bed of salt that formed them. There are more than 500 recorded salt domes in the Northern Gulf of Mexico.

Chemical reactions with groundwater cause the formation of caprock over the salt dome. Rising hydrocarbon products such as oil and natural gas accumulate in crevices and pockets along the edge of the salt dome. Approximately 80% of Gulf oil and natural gas reserves are associated with salt domes. Another mineral resource that accumulates along the edge of a salt dome is sulfur. Along with sulfur salt domes are also mined for their salt and gypsum. Salt domes have within them deep and open caverns that are impermeable to groundwater. The U.S. uses salt domes to store oil as part of the Strategic Oil Reserve Program. At one time consideration is being given to using

PHYSIOGRAPHIC FEATURES

SALT DOMES

salt domes as toxic and nuclear waste sites. Such usage was questioned because the inner structure of a salt dome can only be guessed--giving rise to caution. The question of safety must also be considered based upon history and criticism of the U.S. Department of Energy's management of the Strategic Petroleum Reserve. The inherent dangers of working with a salt dome were demonstrated when an actively mined salt dome in Lake Peigneur, Louisiana was punctured during an oil exploration operation in 1980 draining a lake, pulling in the oil rig, barges, a tugboat, and ten acres of adjoining land.

Activity

Locate salt domes

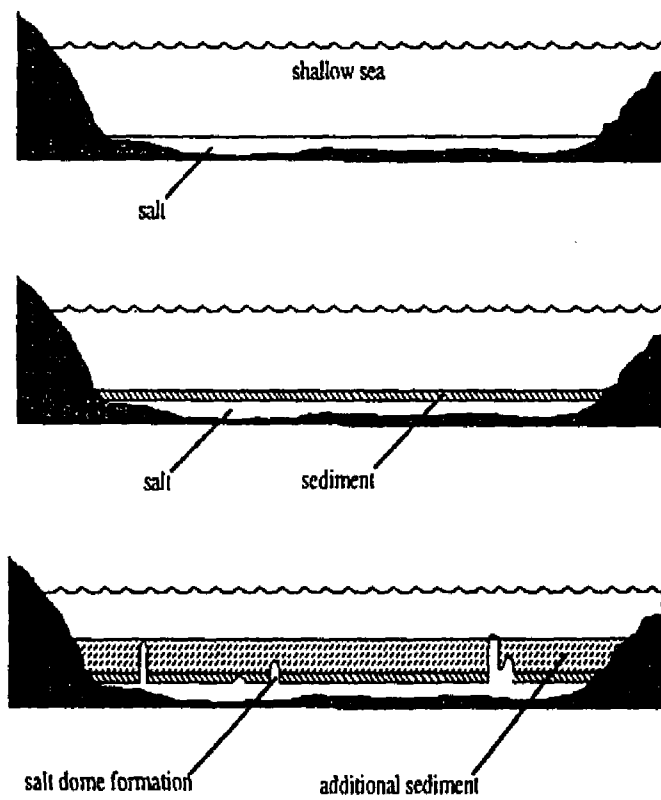
Salt domes can be located on topographic maps of southern Louisiana. The easiest to spot are near Avery Island and Weeks Island in Iberia parish, Louisiana.

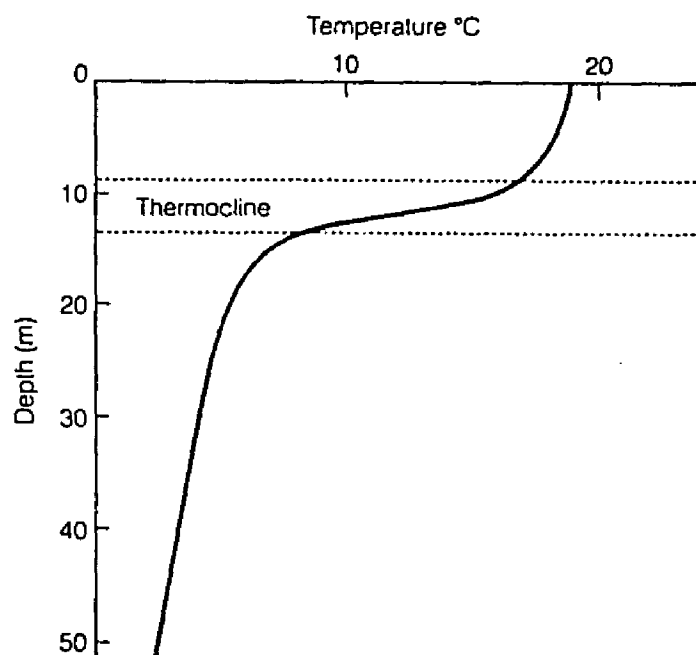
Observe two liquids of different densities

Observe two liquids of different densities in a jar. Place two liquids of different densities in a jar until full. Turn the jar over and observe. Suggested liquids Karo syrup and cooking oil, mineral oil and alcohol, very cold water and warm water. However you pour them, shake, or reverse top and bottom they will separate.

Really salty islands

Tony Mergist, teacher consultant with the Louisiana Geography Education Alliance, has developed activities that require an IBM 486 computer. The activities utilize a Geographical Information System (GIS). If interested contact him through Dr. Phil Larimore, Dept. of Geography and Anthropology, 445 Howe-Russell Complex, LSU, Baton Rouge, LA, 70803.

PHYSIOGRAPHIC FEATURES**SALT DOMES****Salt dome formatin**

PHYSICAL AND CHEMICAL PROCESSES**WATER OF THE GULF**

Typical profile of ocean water temperature. Adapted from Lerman (1986, p. 51)

PHYSICAL AND CHEMICAL PROCESSES

WATER OF THE GULF

In the news

Dispute brewing over salt water intrusion
Tampa Tribune, Oct. 14, 1990

Hearing planned on freshwater diversion
Times Picayune, Dec. 27, 1989

Concepts:
thermocline
salinity
salts
lagoon
estuaries

saltwater
freshwater
osmoregulation
density
nutrients

It seems somewhat strange to say, but the most significant thing about the Gulf of Mexico is that it is full of water. This water has chemical and physical properties that control the dynamics of the Gulf including its ecology. The next thing in order of significance is that this water is saltwater. The Gulf water contains many different salts, chemicals, and organic nutrients.

The most abundant salt among these dissolved salts is sodium chloride. Because there are dissolved salts in seawater it is denser than freshwater. This is important when freshwater enters into the ocean and when saltwater intrudes upstream. The less dense freshwater will travel sometimes 50 miles or more out into the Gulf before completely mixing with the saltwater. This lens of freshwater contains nutrients which may be limited in the surrounding ocean waters. It may also contain sediments which may block light transmission necessary for phytoplankton growth. The density difference between freshwater and saltwater may cause a barrier to mixing of the two water masses. Saltwater being denser will travel along the bottom of passes, inlets, rivers, and canals that it may intrude upon.

The measure of total dissolved salts in seawater is called salinity. The standard for salinity is the total amount of dissolved salts (in grams) in a liter of water or parts per thousand (1 liter = 1000 milliliters and 1 gram of water = 1 ml of water). Typical ocean salinities are 36 parts per thousand or 36 ‰. Most bays and estuaries have diluted salinities due to freshwater input which may vary. However, in Texas, the Laguna Madre is a hypersaline lagoon where salinities can reach 80 ‰. This is because evaporation exceeds precipitation and there is little freshwater input. Animals and plants that live in the ocean, bays, and estuaries must constantly deal with problems of osmoregulation, that is controlling the amount of water in their tissues. Such physiological regulation requires that the organism expends a great deal of energy.

Major chemical components of seawater include:

Chloride
Sodium
Magnesium
Sulfate
Calcium
Potassium

Another factor that controls the density of the water is temperature. The warmer the water the less dense it is.

PHYSICAL AND CHEMICAL PROCESSES

WATER OF THE GULF

When the temperature between two water masses is great enough, a boundary can form that prevents mixing. This is especially evident in strong thermoclines that form during the summer as upper sunlight waters become warmer than colder bottom waters. This density barrier and the compounding density barrier formed by freshwater contribute to a phenomena known as hypoxia or dead zones. Dead zones are discussed later in this book.

Seawater also contains dissolved gasses such as dissolved oxygen and carbon dioxide. Dissolved oxygen (DO) is of primary importance to living organisms. The typical amount of dissolved oxygen in seawater is 5 milliliters per liter or (ml/l). It may vary from zero to 9 ml/l. Hypoxia occurs when levels reach less than 2 ml/l. Consider that the earth's atmosphere is 21% oxygen, organisms that live in water must be more efficient at getting oxygen than terrestrial organisms. Oxygen comes from two main sources in the ocean. The first source is phytoplankton production through photosynthesis. The second source is through diffusion from the earth's atmosphere.

Carbon dioxide (CO_2) is much more soluble in seawater than oxygen. It is an essential ingredient in the photosynthetic process. The ocean can contain 50 percent more carbon dioxide than the atmosphere. For this reason scientist are looking the oceans' ability to alleviate the effects of rising CO_2 levels in the atmosphere. Dissolved CO_2 is also the source for the formation of calcium carbonate which many marine organisms build their shells and skeletons from.

Activity

Melting Ice

Fill a 500 ml graduated cylinder with freshwater and a second cylinder with a supersaturated saltwater solution.

Have students predict in which cylinder would ice melt the fastest in. Write down predictions.

Place equal amounts of ice in each cylinder. After approximately one minute put a few drops of food coloring in each cylinder. Observe.

Discuss any discrepancies between observed results and predicted results and why.

Can you see the difference?

Small groups (4 students per group).

Obtain the following materials: plastic tray, two flasks, laminated card, salt, spoon, and food coloring.

Directions

1. Fill each flask to the very top with water.
2. In one flask dissolve 1/2 spoon of salt and three drops of food coloring. Stir with the other side of the spoon until the salt is dissolved.
3. Place the card over the flask with the colored saltwater and invert the flask.
4. Place the inverted flask with the card over the flask with the freshwater.
5. Align the mouths of the flasks.
6. Pull the card out.

PHYSICAL AND CHEMICAL PROCESSES

WATER OF THE GULF

7. Observe for about 2 minutes and record your observations.
8. Repeat steps 1 and 2 above.
9. Place the card over the flask with the freshwater and invert the flask.
10. Place the inverted flask with the card over the flask with the saltwater.
11. Align the mouths of the flasks.
12. Observe for about 2 minutes and record your observations.
13. Return equipment.

Questions:

1. Is saltwater higher or lower in density than freshwater? Explain.

2. New World explorers found freshwater in the ocean by taste. This was how they discovered the Amazon River. Explain how freshwater could be found 50 miles out in the ocean.

3. At the mouths of rivers, inlets, and passes, fishermen sometimes can catch freshwater fish and saltwater fish in the same place. Offer an explanation.

Possible Extension:

Review the formula for density $D=M/V$ and how it applied to the above activities.

Repeat the activity above using hot and cold water instead of saltwater and freshwater.

Soda Straw Hydrometer

Small groups (2 per group)

Obtain a tray, graduated cylinder, salt, spoon, and small piece of clay.

Directions:

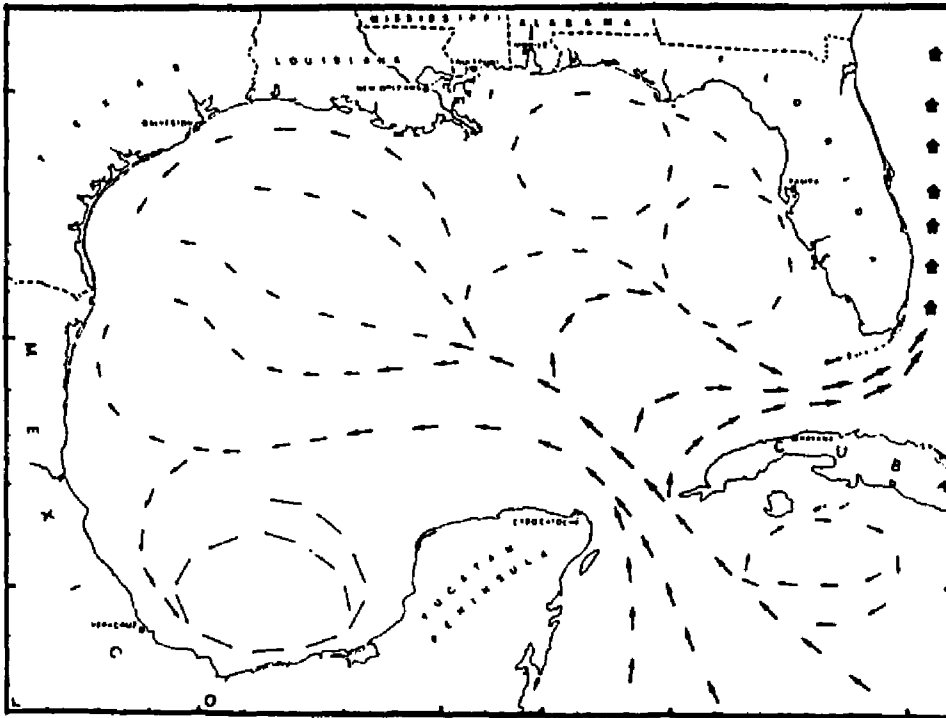
1. Press a small ball of clay into one end of a straw. The clay should act as a plug so water cannot get into the straw.
2. Add freshwater to your cylinder to the 90 ml line.
3. Put the hydrometer in the water. The hydrometer should not rest on the bottom. It should be bobbing in the water with about 1-2 inches of straw sticking out of the water.
4. Mark the water level on the straw and label it zero.
5. Remove the hydrometer. Add 1 teaspoon of salt to the water. Dissolve the salt in the water. Put the hydrometer into the water.
6. Make a mark at the water line and label as 1.
7. Repeat adding additional teaspoons of salt until you get to 4.

Questions:

1. How can we increase the precision of our hydrometer?
2. Are there alternative ways to construct such a hydrometer?
3. What would be the use of having such a tool in the classroom?

Possible Extension:

Prepare unknown solutions of salt in water and have the students determine the amount of salt using their very own piece of scientific equipment.

PHYSICAL AND CHEMICAL PROCESSES**CIRCULATION**

Loop Current system in the Gulf of Mexico. Adapted from Gore (1992, p. 70)

PHYSICAL AND CHEMICAL PROCESSES

CIRCULATION

In the news

Fresh water found in Gulf Stream
The Advocate, Sept. 25, 1993

Concepts:

Loop Current
eddy

Gulf Stream
entrainment

Seawater in the Caribbean Sea set in motion by the sun's heat enters the Gulf of Mexico through the Yucatan Channel. This warm water current becomes a system known as the Loop Current. The Loop Current is a system of shifting spiral currents termed eddies. The most common pattern is where the main current entering the Gulf splits into a westerly current flowing towards Texas and Mexico. The other more dominant split in the mid-Gulf region takes a sharp easterly turn continuing to loop to a southerly flow through the Straits of Florida. This is the origin of the Gulf Stream. The warm water of the Gulf Stream affects the climate of the Eastern Seaboard and the British Isles. Such currents as the Loop Current and the Gulf Stream function to transport heat from the tropics to higher latitudes thus tempering the climate in these areas. This is also important to scientist in trying to develop climate models and understand the ocean's capacity to absorb heat.

Occasionally water from the Mississippi River can become entrained in the Loop Current. This happened to the flood waters that came from the midwest portion of the U.S. during the summer of 1993. It was discovered when salinities were reported lower than usual in the Gulf Stream off Miami. While the above may seem somewhat of a simplistic explanation one must consider the effect of winds, Coriolis effect, bottom topography, and deep water currents to fully understand water circulation in the Gulf of Mexico. Along the boundaries of these currents small spiral currents may

pinch off forming a small scale circular current pattern. The core of these currents may be warm or cold depending on where they broke off. These are then named warm core or cold core rings. Scientist use the term mesoscale eddies to describe these currents. These eddies are quickly formed and are temporary making them hard to predict and locate. Oil companies in the Gulf have lost millions of dollars because of these currents when trying to place rigs over exploration sites. However, now satellite imagery can locate the position of these eddies so currents in a local area can be better predicted.

Activity

Water in motion

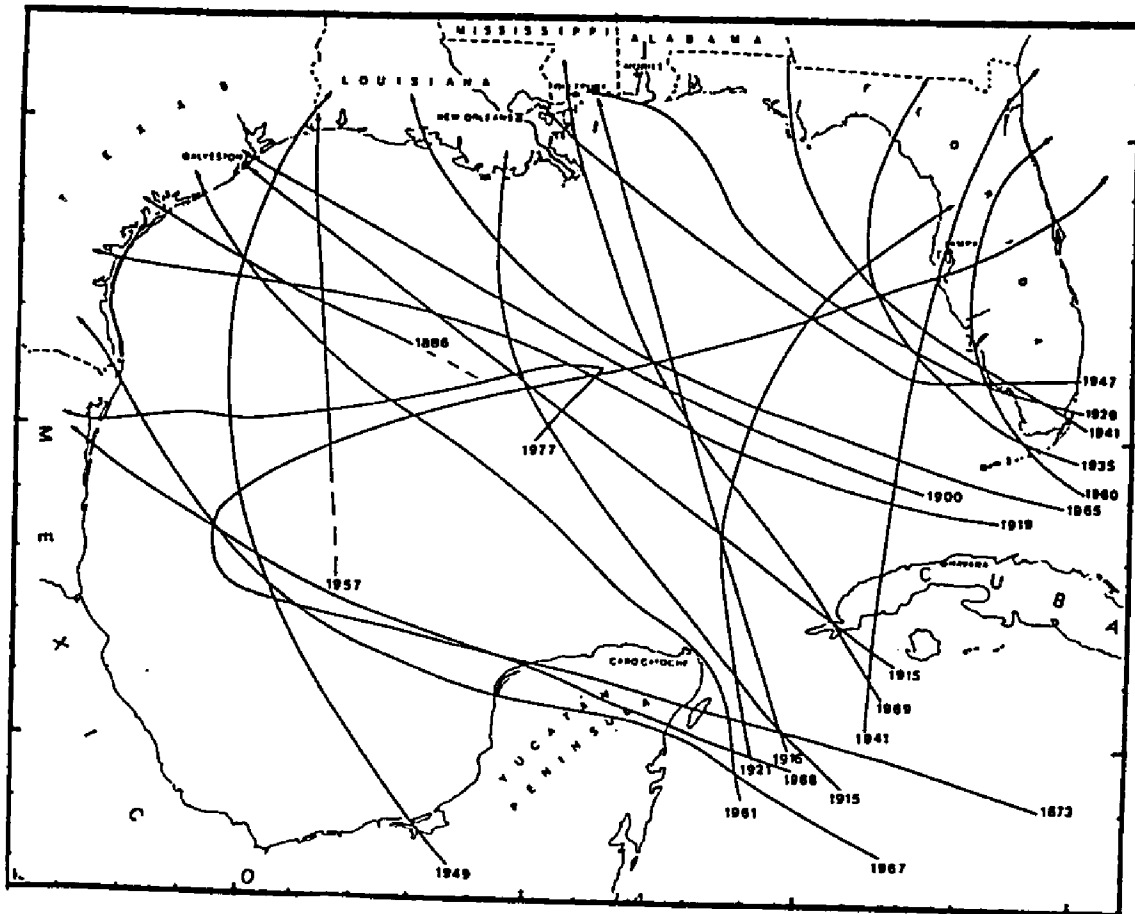
Fill a clear Pyrex lasagna or casserole dish half full of water. Place a heat source such as hot plate (use wire gauze or triangle), Bunsen burner, or candle at one end. Then add a few drops of food coloring into the water that is being heated.

Note: If you do not want to use a heat source as suggested above, use a blow dryer on the end or bottom of the dish.

Trace the path of the water.

Do the above using an array of thermometers and trace temperature change over time.

STORMS



Selected storm tracks illustrating that the entire Gulf is susceptible to hurricanes.
Adapted from Gore (1992, p. 106).

PHYSICAL AND CHEMICAL PROCESSES

STORMS

In the news

Hurricane exposes flaws in storm plans
Tampa tribune, Aug. 29, 1991

Storm was a shocker
Tampa Tribune, Mar. 30, 1993

Concepts:

hurricane
tropical storm
tides
flooding

cold front
storm surge
low pressure system
air mass

Hurricanes are what most people think about relative to large destructive storms in the Gulf of Mexico. They are a threat to human life and property. Tropical storms and cold fronts can also produce excessive rain, high tides and strong winds. Further, people who live in the Southern U.S. experience thunderstorms, which may also be destructive due to wind, lightning, hail, and possible flash flooding.

Hurricanes and tropical storms may form in the Gulf of Mexico or may migrate into the Gulf from the Atlantic Ocean or Caribbean Sea. Hurricanes and tropical storms are also known as cyclones. The warm waters of the Gulf are the fuel for these storms usually increasing their intensity. They form when warm moist air begins to rise because of heat convection and low air pressure. Colder air rushes in to take the place of the rising warm moist air and a spiral counterclockwise wind pattern is formed. As long as there is a source of warm moist air this system perpetuates itself into a larger cyclone with destructive storm forces such as wind, rain, and tornadoes.

With increasing coastal populations the potential for storm disasters has increased. This is evidenced by recent disastrous hurricane hits in the U.S.

where property damage was high. Hurricanes Betsy, Camille, Juan, and Andrew are examples of storms that caused extensive property damage upward into the billions of dollars. In the United States loss of life is now minimal due to advanced forecasting techniques and modern communication. However, officials are still very concerned that a possible combination of factors may endanger human life such as attempting coastal evacuations during a peak tourist season, evacuating large urban areas such as New Orleans, and the flooding or severing of evacuation routes by a fast approaching storm.

Historically, the minimal loss of life was not the case. There are several documented disasters in terms of human loss by hurricanes in the Gulf. One such example is Galveston in 1900 with 6,000 lives lost. In Louisiana, a hurricane hit Isles Dernieres during the summer of 1856 with approximately 400 lives lost and the total destruction of the community. Another community in Louisiana, Caminada, is where 2,000-3,000 lives were lost and the total destruction of the community. The latter two communities were never rebuilt. In recent history, hurricanes Andrew (1992), Audrey (1957), Betsy (1965), Camille (1969), and Juan (1985) are the most

PHYSICAL AND CHEMICAL PROCESSES

STORMS

notable hurricanes because of property damage and number of people killed.

Hurricane Camille, a category 5 storm (see Saffir/Simpson scale on p. 37), killed 259 people and destroyed \$ 1 billion in property. Survivors recall the following:

At about 10:15, in a single stroke, all the lights and electrical power in Pass Christian went out. Fifteen minutes later, a gently rolling wave, as high as a three-story house, slammed over the sea wall and across Beach Avenue, slicing under the brick pillar foundations of \$50,000 homes, demolishing frame houses, climbing up to the second floor and the attic of any building it didn't flatten. (Davis, 1989)

The majority of hurricane damage is because of coastal flooding by extremely high tides, storm surges, and wave action. The high winds of a storm will push water on shore and land. The intense low pressure of a hurricane actually raises the level of the water which may add several feet to whatever tide is being experienced during a storm. Waves will obliterate coastal structures (homes, hotels, bridges, piers, etc.). Further, large amounts of rainfall associated with such storms will cause flash flooding in inland areas. The winds of a category 3 storm (111-130 mph) and stronger storms are most certainly destructive.

Occasionally strong winter cold fronts pass into the Gulf. As it approaches the Gulf or when a leading edge reaches the Gulf this mass of cold air hits warm air and high winds and heavy rains are the result. The recent "storm of the century" that battered the east coast in March 1993 also caused hurricane force winds and a large storm surge along the central West Florida coast.

A generation of hurricanes in the Gulf of Mexico:

1994	Alphonse
1992	Andrew
1990	Diana
1989	Chantal
1989	Jerry
1988	Florence
1988	Gilbert
1986	Bonnie
1985	Danny
1985	Elena
1985	Juan
1983	Alicia
1983	Barry
1980	Allen
1980	Jeanne
1979	Bob
1979	Frederic
1979	Henri
1977	Anita
1977	Babe
1975	Caroline
1975	Eloise
1974	Fifi

Activity

Hurricane evacuation

Obtain a state road map or county/parish map and locate several developed barrier islands. What routes would you take to get away from the coast in the event of a hurricane evacuation? Are there any critical barriers? How many bridges would have to be crossed? What if one of these bridges was disabled by a large accident? (The barge was forced in like many other vessels due to rough seas offshore). Estimate the number of people that would need to be evacuated.

Using the list of hurricanes, determine the frequency of hurricanes (number per year) in the Gulf?

PHYSICAL AND CHEMICAL PROCESSES

STORMS

Hurricane lore

Have students interview people such as relatives about hurricanes they have experienced. What was it like? Were they scared? Did they lose property? Did they have warning that a hurricane was coming? If so, how did they get the warning?

Hurricane tracking

Below is data from hurricane Camille, one of the most powerful storms recorded in the Gulf.

Obtain a hurricane tracking map and plot Camille's path. Where did it make land fall?

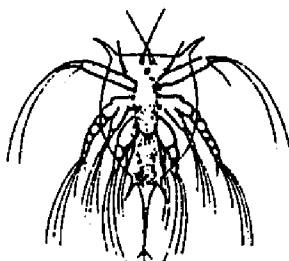
Examine the wind speed data and graph.

Hurricane Camille 1969

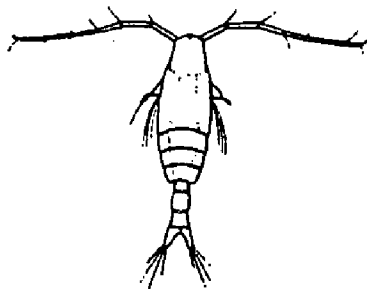
Date (Aug.)	Time (CDT)	Latitude (N)	Longitude (W)	Wind Speed (MPH)
14	1300	19.4	82.0	58
14	1900	19.7	82.7	63
15	0100	20.1	83.3	69
15	0700	20.7	83.8	98
15	1300	21.2	84.1	115
15	1900	22.3	84.4	104
16	0100	23.1	85.2	121
16	0700	23.7	85.9	138
16	1300	24.2	86.5	150
16	1900	25.2	87.2	161
17	0100	26.0	87.7	178
17	0700	27.0	88.2	184
17	1300	28.3	88.7	190
17	1900	29.4	89.1	190
18	0100	30.7	89.6	115
18	0700	32.2	90.0	75
18	1300	33.4	90.1	58

Saffir/Simpson Damage-Potential Scale

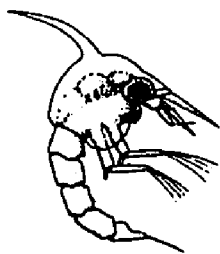
Scale No.	Pressure in Millibars	Pressure in Inches	Winds (mph)	Surge (ft)	Damage
1	980	28.94	74-95	4-5	minimal
2	965-979	28.50-28.91	96-110	6-8	moderate
3	945-964	27.91-28.47	111-130	9-12	extensive
4	920-944	27.17-27.88	131-155	13-18	extreme
5	920+	27.17+	155+	18+	catastrophic

BIOLOGICAL PRODUCTIVITY**PLANKTON**

Nauplius larvae of a barnacle (0.5 mm).



Copepod. The dominant form of zooplankton (0.5 - 5 mm).



Zoea larvae of a crab (0.5 -2 mm).

BIOLOGICAL PRODUCTIVITY

PLANKTON

In the news

Red tide causing death of thousands of fish
Tampa Tribune, Sept. 13, 1992

Red tide bloom grows off Longboat and Lido keys
Tampa Tribune, Nov. 28, 1992

Concepts:

plankton
zooplankton
primary production
biomass

phytoplankton
DOC
trophic level
crop

Plankton are generally microscopic plants and animals that float at or near the surface of the water. They are drifters because they are at the mercy of wind and currents unable to control their own destination. Phytoplankton, the plant like plankton, are primary producers. They utilize sunlight and nutrients from the water to photosynthesize carbohydrate in the form of sugars. This is called primary production. This crop of phytoplankton is the basis of the food chain and trophic structure. The phytoplankton itself creates a crop of biomass that may be consumed by primary consumers. Also because of the watery environment and fragile nature of their cells, phytoplankton leak dissolved organic carbons (DOC) into the water. DOC is the source of nutrition for many organisms.

The two most common types of phytoplankton are diatoms and dinoflagellates. Planktonic diatoms have silica shells and may be found individually or in chains of diatoms of the same species. Dinoflagellates have two transverse flagella and may be armored and ornate. Some dinoflagellates cause red tide and shellfish contamination.

The phytoplankton will be consumed (cropped) by the zooplankton, the animal plankton. The dominate zooplankton organism is the copepod. A copepod is a crustacean animal similar to a shrimp, but

much smaller. Copepods are of sufficient size that they may be consumed by other zooplankton, larval fish, and planktivorous fish such as anchovies and menhaden. Anchovies are important to the food webs in the ocean because they are one of the few fish that consume plankton. Therefore, anchovies are a link from one trophic level to another. The commercial importance of menhaden is discussed under finfish.

Zooplankton may be categorized as being part of the holoplankton or meroplankton. The holoplankton are animals that remain in the plankton their whole life such as copepods. The meroplankton consist of the animals that are only temporarily in the plankton such as the larval forms of barnacles and crabs. The majority of large marine animals have a planktonic life stage.

Activity

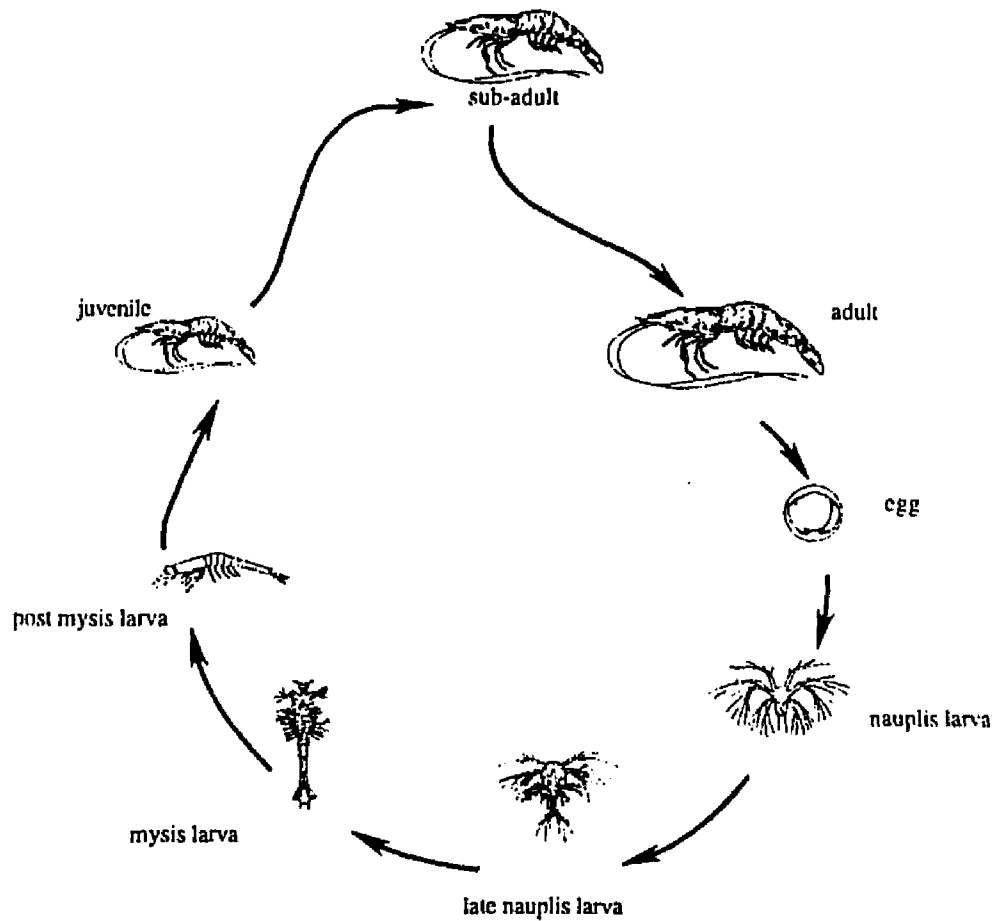
Examine some live or preserved plankton.

Note the various size differences. Consider what organism consumes what other organisms.

Draw a plankton food chain based upon what you have seen.

BIOLOGICAL PRODUCTIVITY

SHRIMP



Shrimp life cycle

BIOLOGICAL PRODUCTIVITY

SHRIMP

In the news

Shrimper watching old ways die hard
Times Picayune, Aug. 29, 1990

Shrimpers vow to defy law on TEDs
Times Picayune, Apr. 9, 1989

Concepts:

fishery
crustacean
bycatch

shrimp
TEDs
endangered species

Shrimp are the premium cash crop from the Gulf of Mexico. For the states of Florida, Alabama, Louisiana, and Texas it brings in more money than any other fishery resource. The Gulf of Mexico is characterized by the large shrimping fleet in its waters. Shrimp are the second most valuable fisheries harvest in the U.S. Most of these shrimp come from the Gulf. A slump in the oil industry has sent more people into shrimping. Seeking work, more people are going after an overfished limited resource. There are 3 species of shrimp that constitute the majority of the shrimp catch and often creating distinct shrimp seasons based on life cycle characteristics. These are the brown (*Penaeus aztecus*), white (*Penaeus setiferus*), and pink shrimp (*Penaeus duorarum*).

Shrimp are a crustacean animal like crabs and lobsters. Its meat when cooked and peeled is white, has a firm texture, and a slightly sweet taste. It can be served in an endless variety of ways from boiled hot and boiled cold, as an appetizer, shish-ke-bob, stir fry, fried, or dried to name a few.

Mature shrimp spawn in the Gulf's offshore waters. Fertile eggs hatch into planktonic larvae which goes through a series of molts. During the larvae and postlarvae stage the shrimp enter the estuaries. They feed on the concentrated food supply of algae, microfauna, and detritus. The survival and growth of these

young shrimp are dependent on local salinity and temperature. The Gulf of Mexico Fishery Management Council noted that the weakest link in the life cycle chain is the estuarine growth phase which is out of their jurisdiction. Alteration of freshwater flow and habitat loss could result in a decrease of the shrimp fishery (see section on habitat loss). Shrimp are truly estuarine dependent species (see section on estuaries).

Shrimping has taken the spotlight recently because of controversy surrounding the use of "Turtle Excluder Devices" or known as TEDs. It seems that shrimp nets catch many other things beside shrimp. Slow swimming seaturtles are one such organism caught in nets. Turtles are air breathing and when caught in a net they drown. Since all seaturtles are endangered species and one in particular the Kemp's Ridley turtle is near extinction, the National Marine Fishery Service required shrimpers to install and use TEDs. Shrimpers who are ferociously independent were resistant to new government regulations. Another concern with TEDs which galvanized the shrimping industry was the claim of loss of catch due to TEDs. If they let out turtles, they also let out a significant portion of the catch. Further, large amounts of seaweed could also open the trap door causing another loss of catch.

The issue has died down and there seems to be a large degree of compliance,

BIOLOGICAL PRODUCTIVITY

SHRIMP

but a new issue is coming to the horizon with equally important controversies. That issue is "bycatch." Bycatch refers to all the other organisms caught in the net. The process of being caught in the net and put on the hot deck of a boat generally kills most of the catch. Managed species such as the red snapper are suffering population declines because their juveniles are part of the bycatch. Watch the papers because this will be a good case study.

Activity

See what happens

Locate a newspaper article or magazine article on bycatch. Make a chart labeling the people involved and their position.

Are there other issues here? What is your solution?

Read the data

Examine the landings and value of shrimp over the last ten years.

Are there any trends? When was the best year and the worst year for value? For landings?

Consider there are more shrimp fishermen now than there were ten years ago. Will they earn more or less money? Why?

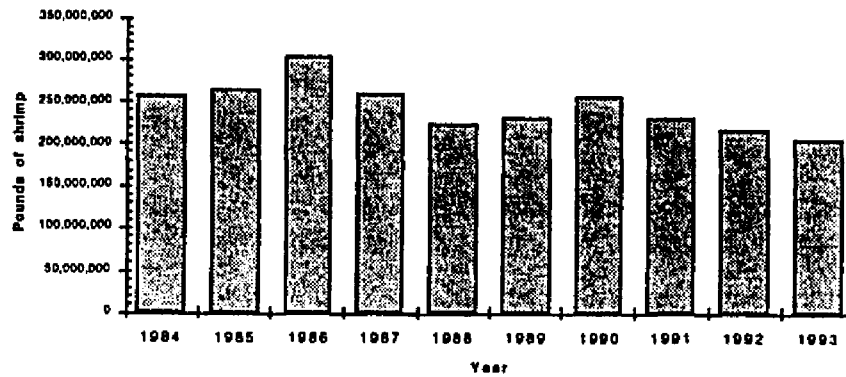
Shrimp landings for the Gulf of Mexico

Year	Pounds	Value	Price per pound
1984	256,587,075	\$431,021,365	\$1.68
1985	264,438,179	\$405,753,453	\$1.53
1986	305,879,087	\$565,991,940	\$1.85
1987	259,355,024	\$477,569,140	\$1.84
1988	225,441,184	\$409,444,785	\$1.82
1989	232,034,271	\$385,274,846	\$1.66
1990	255,435,914	\$412,060,259	\$1.61
1991	231,251,238	\$423,494,703	\$1.83
1992	218,671,868	\$381,999,632	\$1.75
1993	205,287,802	\$335,640,213	\$1.63

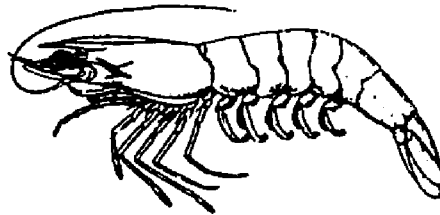
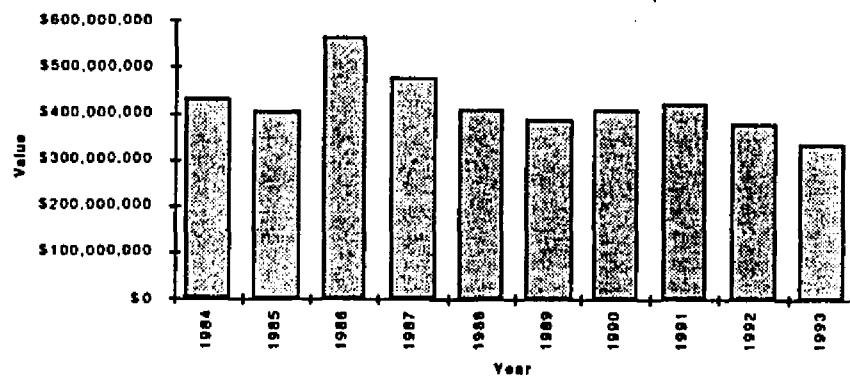
BIOLOGICAL PRODUCTIVITY

SHRIMP

Gulf shrimp landings

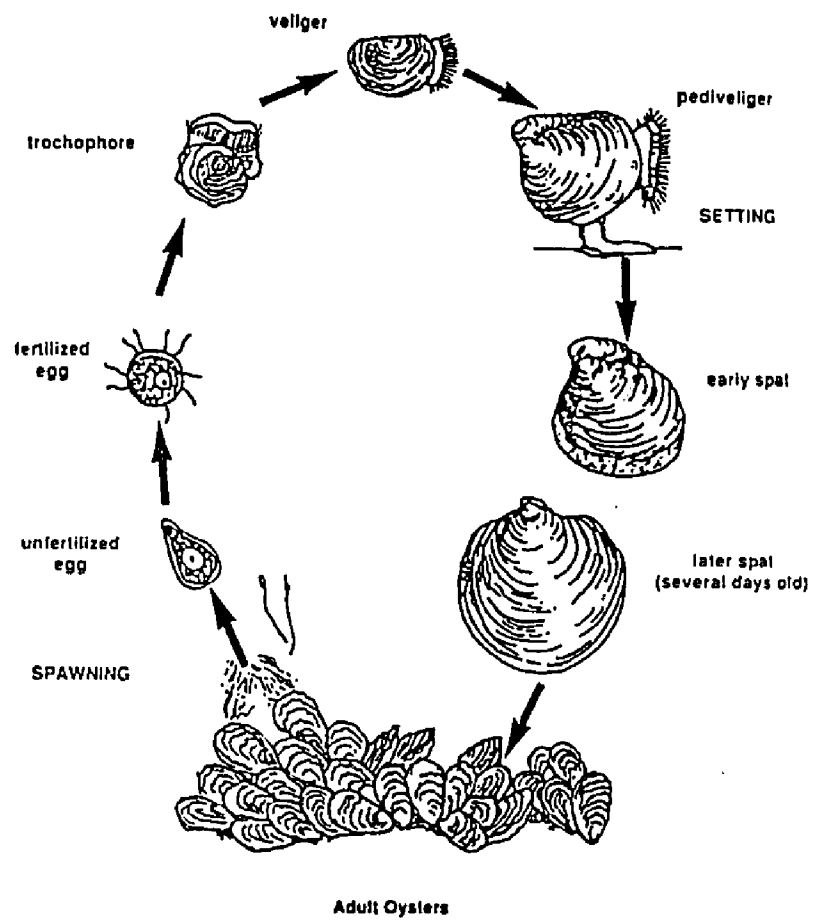


Gulf shrimp value



BIOLOGICAL PRODUCTIVITY

OYSTERS



Life cycle of the Eastern oyster.
Adapted from of University Maryland Sea Grant Program (1979, p. 13)

BIOLOGICAL PRODUCTIVITY

OYSTERS

In the news

Public comes before oyster at state health department
Mobile Register, Feb. 04, 1993

Oysters: Freshwater bringing death
Time Picayune, Jun. 22, 1991

Concepts:

substrate
pathogen
bacteria
red tide

mollusk
virus
depuration
dinoflagellates

Oysters are another icon of Gulf coast cuisine. Many people eat them raw, on the half shell, and others cook them in a variety of ways. Because of diseases in East coast oysters and water quality problems, the demand for Gulf coast oysters has increased over the last few years. Large middens of oyster shells left by Native Americans indicate that it has been a food source for thousands of years.

The oyster is a bivalve mollusk like a clam or scallop. There are many different species of oysters, but the one we are considering here is the American oyster, *Crassostrea virginica*. It has a planktonic larval stage and settles on hard substrate (other oyster shells do just fine). When they settle they become immobile and are susceptible to a variety of environmental changes, perturbations, and predators. They grow well in saltwater, but that is where their predators reside. Successful oyster populations tend to be in brackish water or in intertidal areas out of reach from predators.

Oysters depend on good water quality for good growth rates and reduced mortalities. Oysters are filter feeders and concentrate bacteria, viruses, and toxins naturally as well as from polluted waters. *Escherichia coli*, a bacteria of the mammalian gut, is found in many of the

coastal waters. The presence of this bacteria will cause health officials to close those waters for the taking of oysters. The use of septic tanks in coastal areas is the largest source of such bacteria. Other pathogens that are concentrated in oyster tissue may be red tide causing dinoflagellates. Occasionally people get sick from eating raw or undercooked oysters. The largest type of pathogen responsible is marine vibrio bacteria. Cooking the oyster kills such pathogens.

In the spirit of American entrepreneurship companies are experimenting with purification techniques hoping an oyster held under certain conditions will purge itself of pathogens. This work is currently experimental and under study by biologists and health officials. Like other seafoods the safe storage and handling of oysters insures a good product.

Activity**LIFE WITH AN OYSTER
PROCESSES OF LIFE**

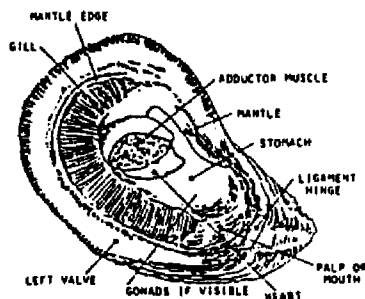
Activities with Oysters
By Babs Ware

BIOLOGICAL PRODUCTIVITY

OYSTERS

INTRODUCTION

The oyster *Crassostrea virginica* found along the Louisiana coast is an ideal animal to use for classroom activities. It is easy to obtain and maintain in the classroom. Your local seafood market has a ready supply. Instant Ocean, or any other commercially available sea salt mixture, is used to create a marine environment that will successfully maintain your animals. Simply follow the directions on the back of the package. The activities in parts I, II, and III require that the oyster be shucked or "on the half shell." This is accomplished by inserting an oyster knife between the two halves of the shell and cutting the adductor muscles. You may now remove the upper valve or shell and clearly view the oyster. The shell should be saved to cover the oyster to prevent dehydration during wait times. The drawing below will help you to identify the parts of the oyster



PRELAB DISCUSSION

QUESTION: What would you use to help you to decide if an organism is alive? List as many things as you can.

When we ask our students to make a list of items we can use to determine if something is living, it more than likely their list will include things that we use to determine if a human being is alive, such as breathing, movement, or heartbeat. This list is not applicable for determining life in

all living things. Before we begin this lab activity make sure the student has a firm understanding of the factors we use to determine life. The list should include: made of cells, growth, food getting, excretion, metabolism, reproduction, has a life span, irritability or response to a stimulus. The activities will cover some of these areas.

Activity I. IRRITABILITY

Irritability is a response to a stimulus. The easiest way to determine if an oyster is alive is to use a probe or a needle to elicit a response. When a living oyster is gently probed it will respond by pulling away from the source of the irritation. You can probe the mantle or the visceral hump. Repeat the probing after a two minute interval.

Materials: probe or needle

1. How did the oyster respond to the stimulus?
2. Did the oyster respond the second time it was stimulated?
3. Give an example of a response you would make if you were stimulated in the same way.

II. FOOD GETTING

Oysters are filter feeders or mucus feeders. Because they are sessile, or attached, they must collect their food from the water that washes over their bodies. They draw water into the shell using an incurrent siphon. Water is expelled from the shell from the excurrent siphon. Food particles in the water are trapped by the mucus found on the gills. Once this food is collected from the water, it is moved to the mouth by the motion of cilia. You will be able to see this movement by placing a drop of food coloring (red is easier to see) on the gills and watching carefully using a hand lens or magnifying glass.

Place a drop of red food coloring on the gills. Use a hand lens or magnifying

BIOLOGICAL PRODUCTIVITY

OYSTERS

glass to observe the movement of the food coloring.

1. Describe what happened to the drop of food coloring
2. Describe how the cilia look and how they move.
3. Where did the dye go? Why?
4. How long did it take for the food coloring to reach the mouth?

III. HEART BEAT

The heart is very easy to view once it is pointed out. Oysters have a circulatory system and blood, but it is not red like ours. The blood is not always found in a blood vessel like ours either. This kind of circulatory system is called an open circulatory system. Use the drawing to help you locate the heart of the oyster. Watch it carefully. You will be able to see it beating. Count the number of beats for one minute. Place the oyster in the refrigerator or on ice for 5 minutes. Count the number of heart beats again.

1. What is the temperature of the classroom?
2. How many times does the heart beat in one minute at room temperature?
3. How many times a minute does the heart beat when the oyster is cold?
4. Why is there a different number when it is hot and when it is cold?
5. Why do people put ice on the oysters before they sell them to you?
6. When you buy oysters at the store or when you eat them "on the half shell" are they living or dead?

IV. REPRODUCTION

Oysters spawn in late spring or early summer in response to warming water temperature or the presence of oyster gametes (egg or sperm) in the water. The other oysters in the oyster bed will detect the presence of gametes in the water as they feed. This will trigger them to release their own gametes into the water. The effect is that the entire oyster bed spawns virtually in unison. This mass spawning insures that fertilization will occur.

At the front of this section on oysters is a copy of the life cycle of the oyster. The oyster larvae must attach to a firm substance or substrate before it can begin to feed. This process of attaching is called settling. The larvae attaches to the shell of a larger oyster (which provides a firm substrate). As the larvae grows it becomes a young oyster. The young oyster is male. This small oyster continues to grow and, when it reaches a certain size, it will change its sex and become female. The term that describes this process is protandric. Isn't it convenient that the young oyster that is male is attached to the shell of a female? What a marvelous reproductive strategy!!!

To simulate the conditions found in nature, you can cool the oysters in the refrigerator overnight. Place the oysters in a bucket of warm sea water (between 75 -80 degrees Fahrenheit). This warming will trigger the release of gametes. Another way to force the oysters to spawn is to make a shallow cut in the visceral area above the gills. This will release gametes, and trigger others to spawn. To insure that fertilization will occur, be sure to include small oysters in the bucket too.

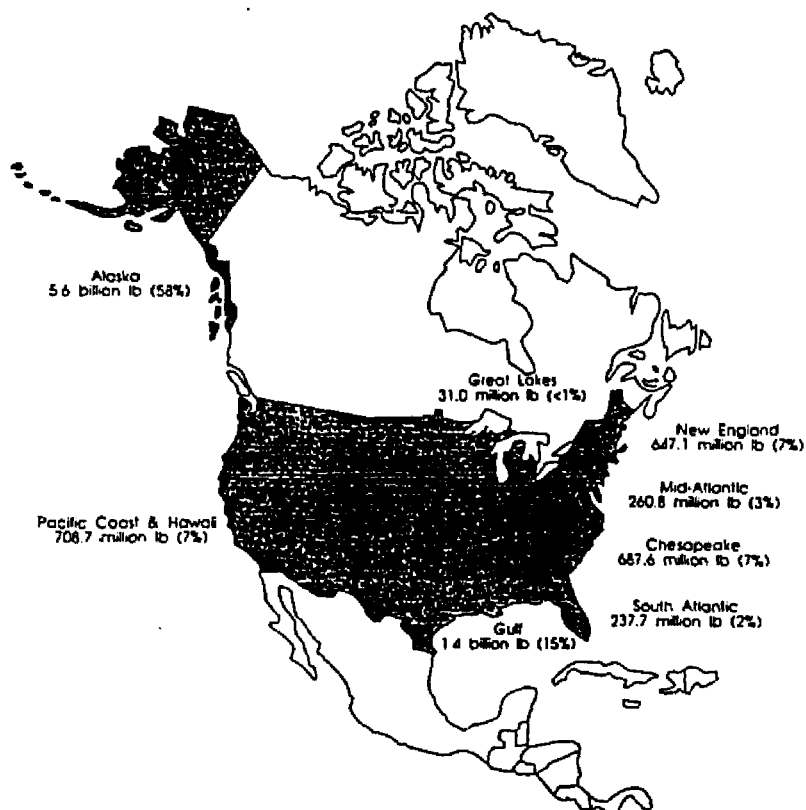
Materials: buckets and warm sea water

1. Are there any small oysters attached to the larger oysters?
2. What is the purpose of having small oysters in the bucket?
3. Why is it important that all the oysters in the same bed spawn at the same time?

BIOLOGICAL PRODUCTIVITY

FISHERY RESOURCES

U.S. COMMERCIAL LANDINGS BY REGION



BIOLOGICAL PRODUCTIVITY

FISHERY RESOURCES

In the news

Red snapper endangered, fishery experts say
Corpus Christi Caller, Oct. 13, 1988

Gulf crews net big profit from inedible fish
Times Picayune, June 6, 1989

Concepts:

finfish
management
menhaden

primary productivity
by-catch
sport fishery

The high level of primary productivity by phytoplankton and other sources is able to support a trophic structure with large populations of fishes. Many of these fishes are commercially and recreationally important such as the menhaden (also called pogy, pronounced as poe-ghee), speckled trout, redfish or red drum, tuna, red snapper, grouper, mackerel, and flounder.

The most abundant fish caught in terms of number and tonnage is the Gulf menhaden or pogy (*Brevoortia patronus*). While it is a large part of the Gulf of Mexico fishery many people don't know about this fish. The reason is menhaden are not sold in seafood markets or any restaurants. This fish is very oily, has many bones, and has a strong fishy smell. These are not the qualities that make a fish attractive for human consumption. When landed these fish are taken to a processing plant commonly called a pogy plant. These plants are characterized by the distinctive bitter acrid smell of processed pogy. The fish is processed into a fish meal and the oils are extracted. The oils are used in the cosmetics industry and in margarines. The fish meal is used for animal feeds, protein supplements for underdeveloped countries, and fertilizers.

The redfish, speckled trout, red snapper, king mackerel, and other fish are managed species. This means the

National Marine Fisheries Service has regulations such as seasons, quotas, type of gear, and size limits for catching these different fish. The management of redfish and speckled trout has caused controversy between commercial and recreational fishermen. Essentially both want access to these fish. However, the commercial take was so great that there was a decline in the fish populations. While commercial fishing of these two species has been stopped or extremely limited, there is still a recreational fishery allowed. Declining numbers of red snapper are making officials look at shrimping practices that destroy a large number of juvenile snapper in the bycatch. Bycatch is all the extra stuff in a net trawl besides shrimp (see shrimp section).

There are numerous social, political, and economic issues surrounding any large fishery especially if it is a managed fishery. The commercial fishermen want to make a living, but there must be a sustained population of fish to continue his livelihood. Commercial fishing also supports a vast industry that creates many jobs from dock workers to a cook at Red Lobster. Unfortunately, it seems that the commercial fishermen is at the low end of the profit sharing of this industry. Therefore, new regulations, increasing gas cost, competition from recreational fishermen, increased number of commercial fishermen, increased

BIOLOGICAL PRODUCTIVITY

FISHERY RESOURCES

catches because of more efficient technology, lack of political clout, and declining fishery stocks make the business of commercial fishing an insecure profession. It is recognized that sport fishermen will spend more money in the local fishing area than the commercial fishermen. The recreational fishermen must rent or buy boats, buy food, bait, fishing equipment, rent room space, and use marinas. Further many of these sport fishermen are in financial brackets that make them a few steps closer to politicians for their fishery concerns.

There have been historical collapses of fisheries in the world such as the Peruvian Anchovy and California Sardine. The Gulf of Mexico fishery is not immune from a collapse of its many fisheries. Prediction of stocks and management seems to be a gamble of sorts. Managers are dealing with populations that experience natural fluctuations, unpredicted natural disasters like hurricanes, decreasing water quality, climate change, unregulated or under-regulated fishing, and increased fishing pressure. The New England fishery of cod, haddock, and flounder is currently on the verge of collapse. It can be predicted that many of these fishermen will come to the Gulf of Mexico in an attempt to continue their independent lifestyle thus adding to fishing pressure in the Gulf of Mexico.

Currently the out of the top ten ports for commercial fishery landings are in the Gulf of Mexico-four in Louisiana and one in Mississippi.

Fishermen and managers have enough historical and modern data at their disposal to insure a sustainable fishery in the Gulf of Mexico. The practice of limited entry is being discussed among fishery managers which only allow a certain number of vessels to fish. Whatever the solution it will not be easy

and it will mean the end of some jobs. Every resource has its limits.

Other Fishery Resources

While menhaden, shrimp, and oysters do capture the majority of the commercial fishery resources in terms of money and landings (tonnage) there are numerous other important organisms especially shellfish to consider.

The blue crab (*Callinectes sapidus*) another American favorite seafood is bountiful in the Gulf of Mexico. Coastal residents enjoy sitting at a table with a tray full of boiled crabs, cracking and picking out the crab meat. Inlanders don't relish picking their own crab meat, instead buy it already processed. Of course for reasons of freshness and health, whole fresh crabs don't make it too far inland either. Nevertheless crab meat is in great demand across the nation. Another crustacean that is mostly found in Florida waters is the spiny lobster. This lobster does not have the big claws that the American lobster has, but the tail meat is just as good. Stone crabs, again found mostly in Florida's waters, are another tasty addition to the seafood bounty of the Gulf of Mexico. They have large claws with plenty of meat that some say taste better than lobster. The crayfish industry is now a national and international market as opposed to 10 years ago when it was only a local market.

Mollusk such as scallops, squid, and hard clams are also found in the Gulf of Mexico, and make an economic contribution to Gulf of Mexico fisheries. Though not an edible seafood, another minor fishery exists for sponges found off Florida's coast.

Mariculture of fishes and shellfishes will be a possible future industry in the Gulf of Mexico. Currently there are several places where pond and cage

BIOLOGICAL PRODUCTIVITY

FISHERY RESOURCES

culture seems to be successful in producing harvestable fish. The development of large scale operations may be difficult. One such difficulty is the cost of coastal land. Land cost are always rising because of population and tourist demands. This can make the cost of such operations prohibitive.

Activity

The price to beat

Have students visit a grocery store or seafood market and compare the price of

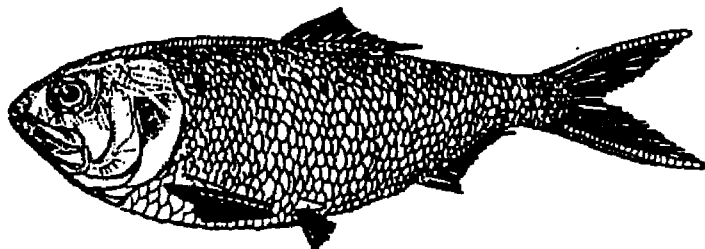
different fishes, hamburger, pork chops, and chicken.

Age of fish

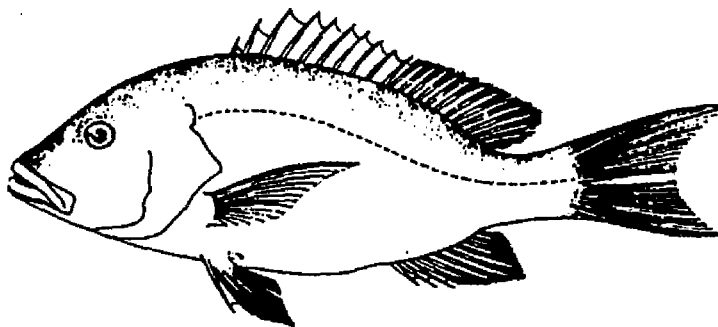
Obtain some fish scales and soak in soapy water overnight. Rinse.

Place between two glass slides and examine under a microscope. There will be distinct rings. These rings will appear in groups. Where they get closer together and appear darker would represent winter growth or an annuli.

Count annuli present.

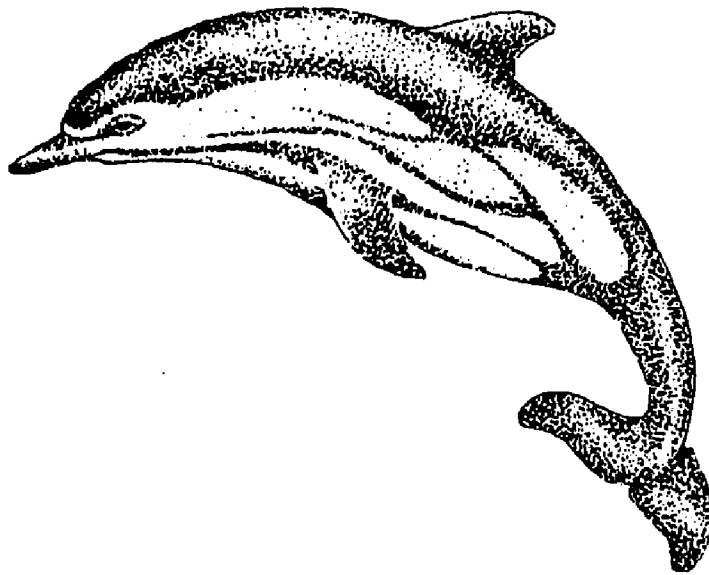


Gulf Menhaden or Pogy



BIOLOGICAL PRODUCTIVITY

MARINE MAMMALS



BIOLOGICAL PRODUCTIVITY

MARINE MAMMALS

In the news

Dolphin deaths prompt 3-month ban on capture
Tampa Tribune, Mar. 16, 1990

Records show high death rate for dolphins held in captivity
Tampa Tribune, June 11, 1990

Concepts:

marine mammal
dolphin
population
toxin

endangered species
manatee
sanctuary
heavy metal

The most common marine mammals encountered in the Gulf of Mexico are dolphins and manatees. Twenty-nine species of cetaceans, one sirenian, and one exotic pinniped have been sighted in the Northern Gulf of Mexico. Although there are numerous whales (cetaceans) in the Gulf, we rarely get a chance to see them because they prefer the deeper more open waters. Dolphins (a cetacean) and manatees (a sirenian) are found in coastal waters and are more easily observed. Many of the whales found in the Gulf of Mexico are endangered species such as the sperm whale and humpback whale. An occasional seal (a pinniped) is reported in the Gulf, but it is assumed that the seal was an escapee from a marine park or an illegal pet that was released. The Caribbean (West Indian) monk seal once found in Gulf waters is now extinct.

The most common mammal in the Gulf is the bottle nose dolphin, *Tursiops truncatus*. They are frequently seen following boats or feeding in the surf at beaches. They are social animals often seen in groups called pods. Dolphins are higher order consumers relying on healthy fish populations to sustain them. Dolphins are known for their ability to echolocate for the purposes of communication and navigation. The dolphin sends out a series of sounds or

clicks. These sound waves bounce off objects and return as the echo. It is the same principle as sonar. The dolphin then analyzes and interprets these return signals as to location, texture, density, movement, and direction of objects or organisms. Like other marine mammals they have blubber, a thick layer of fatty tissue to insulate themselves from the relatively cold water (remember they are warm blooded). Many toxins and heavy metals accumulate in fatty tissues. Therefore, the health of dolphins can be an indicator of the health of the Gulf.

The West Indian Manatee, *Trichechus manatus*, prefer the warmer waters off of Florida spending most of their time in seagrass beds. These gentle unique creatures have become a symbol for endangered species. Like other marine mammals they can hold their breath for considerable periods of time, in the manatee's case up to twenty minutes. During the winter they move into the estuaries and rivers of Florida seeking warmer water relative to the cooler Gulf waters. Their natural behavior of floating near the surface and eating aquatic plants is a major reason why they are endangered. This behavior makes them susceptible to being run over by boats and being seriously injured by boat props. In

BIOLOGICAL PRODUCTIVITY

MARINE MAMMALS

fact most manatees encountered bear the scars of boat props on their back. Loss of habitat also threatens the manatees' existence. Florida now has large manatee sanctuaries where boats may not enter or must idle through.

The National Marine Fisheries Service (NMFS) operates a marine mammal stranding network with the authority of the Marine Mammal Protection Act. Their purpose is to facilitate communication and cooperation between institutions, agencies, and individuals concerned with the salvage of live stranded marine mammals and the collection of scientific data from both live and dead stranded animals.

The issue of captivity arises from time to time. Some individuals and groups question whether or not marine mammals should be held in captivity. Issues include lower life span, captive conditions, and profit motives. Operators of marine parks claim that part of their work is rescue and a large number of their captives are rescued animals and not able to survive in the wild. Another important function that marine parks claim to serve is captive breeding programs. In past few years captive marine mammals have successfully mated and births have resulted. This may be important when trying to breed in captivity endangered species for the purpose of restocking wild populations. However, the important function of public education seems to overshadow most concerns. The ability of a marine park to educate the public about endangered species, unique animals, and aesthetic appeals allows them to capture and retain a few marine mammals.

Commonly sighted marine mammals in the Gulf:

- great sperm whale
- pygmy sperm whale
- short-finned pilot whale
- Atlantic bottle nose dolphin
- striped dolphin

Atlantic spotted dolphin

Activity

Diving Bradycardia
adopted from PROJECT: FOR SEA

Need:
towels
cold water
dish pan
stopwatch

Humans as mammals can exhibit a reflex action called the mammalian diving reflex. This reflex lowers the rate of heart beat and temporarily shunts blood away from the arms and legs. When evoked a pronounced drop in heart rate can be measured.

Work in pairs or select 4 students.

Determine an at rest pulse rate (beats per minute) for a couple of students and record.

Have the same students have them hold their breath for 30 seconds. Take pulse rate during the last 15 seconds of that same period of time and record.

After about three minutes when the students heart rate has returned to normal have the students place their forehead and face into a pan of cool water for 30 seconds. Take their pulse rate for the last 15 seconds of that time and record.

Note: If using the water is a problem substitute cold wet towels held against the face.

The diving reflex is evoked by cold water on the face and the facial nerves. Think of a marine mammal like a whale diving and going below the thermocline and experiencing cold water face first. Think of a seal with its face out of the water and then diving face first into the water.

BIOLOGICAL PRODUCTIVITY

MARINE MAMMALS

These are the conditions in which the diving reflex is evoked.

Think of human birth when there is a brief period of oxygen deprivation because the baby is no longer receiving oxygen enriched blood from the mother because the placenta has broken away from the uterine wall. If the birth is going smoothly the face of the baby comes out into the relatively cooler environment.

Is there any advantage to this?

Cold water drowning victims sometimes are revived even though they have been in the water long enough that it should not be possible. Why?

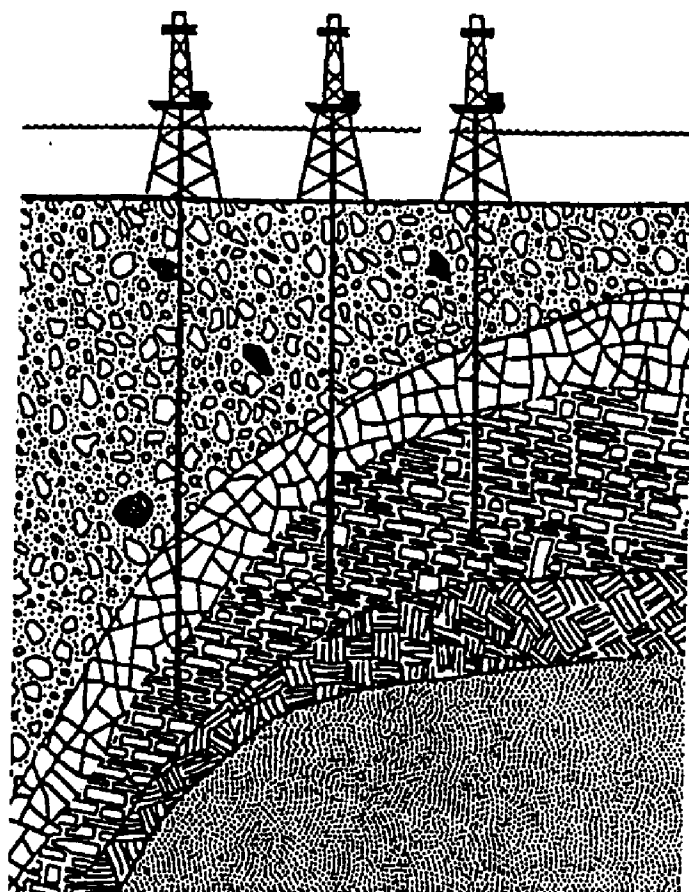
Why do you think it is important for a marine mammal to be able to evoke bradycardia? A sperm whale can stay down for 45 minutes and the record dive is by a Weddell seal with a 90 minute dive.

Free Willie

Should any organization be allowed to capture marine mammals?

Discuss pros and cons. What are the issues? Who are the special interest groups? Once identified you may want to do role playing.

Is the Marine Mammal Protection Act at odds with the Endangered Species Act?

HUMAN IMPACT**MINERAL RESOURCES**

HUMAN IMPACT

MINERAL RESOURCES

In the news

Spill's effect on wildlife assessed
Corpus Christi Caller, July 17, 1988

Ban on Gulf oil drilling survives House negotiation
Tampa Tribune, Oct. 02, 1990

Concepts:

mineral
crude oil
OCS

natural gas
canals
hydrocarbon

The Gulf of Mexico is home to the world's largest offshore oil and gas industry. Since its beginning in the late 1930s the industry has expanded and peaked in the mid-1970s. After that the price of oil and natural gas dropped and further extensive exploration became uneconomical. Presently, the search for natural gas has increased because it is a cleaner burning fossil fuel than crude oil products. Also, the discovery of large deposits and the advancement of deep water drilling technology contribute to the exploration for natural gas. Other mineral resources in the Gulf include halite for salt, sulfur for acids and fertilizers, and phosphate rock for fertilizers. There is a developing interest in the sand (for cement) resources the Gulf has to offer.

The oil and gas industry certainly brought an economic boom to relatively poor southern states, but it created a tremendous environmental impact. While an oil platform standing in Gulf waters may not be a huge polluting machine, the industry that supports it has a larger environmental impact. The port facilities and vessel traffic needed to support the oil and gas industry is harsh on coastal waters and marshes. The sheer number of pipelines needed to transport extracted material created a network of canals. Canals were also cut for exploration drilling. Canals alter hydrology and

sedimentation which contribute to coastal wetland loss.

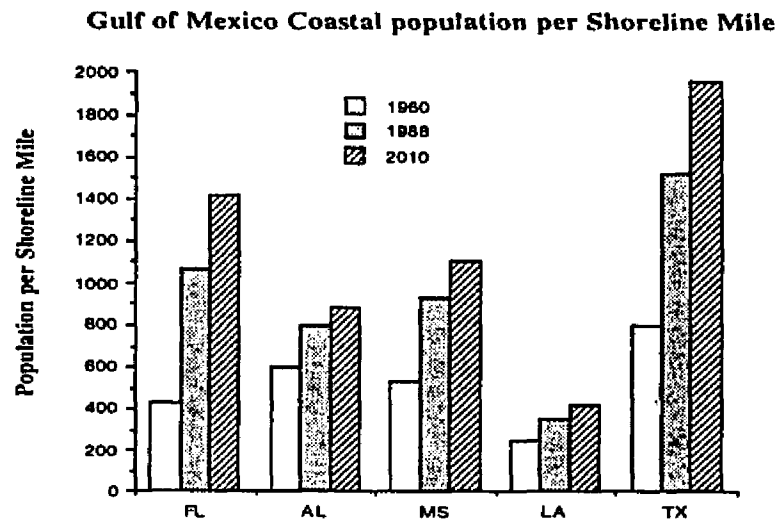
The slurry of material that has been extracted from offshore wells contains a large volume of water. At onshore facilities the oil is separated from the water and the water discharged. This discharged water (called produced water) still has some remaining hydrocarbons in it, is slightly radioactive, and high in salinity. Such discharges may adversely affect plants and bottom dwelling organisms. However, discharges into sensitive areas has declined and the oil companies are having to inject this waste into deep wells.

The economic impact of this industry is tremendous. The second largest contributor to the U.S. Treasury behind income tax is the New Orleans office of the Minerals Management Service (MMS). MMS is responsible for overseeing the Gulf production, environmental impacts, and the leasing of sites.

Activity

Where did the oil come from?

Speculate about how the oil was formed in the Gulf. Compare it with the process of coal formation?

HUMAN IMPACT**HABITAT DEGRADATION**

HUMAN IMPACT

HABITAT DEGRADATION

In the news

Bureaucrats get feet wet on erosion tour
Time Picayune, Dec. 12, 1989

Dramatic decline noted in birds of Mobile Bay
Mobile Register, Dec. 19, 1993

Concepts:

habitat
subsidence
barrier islands
turbidity

natural resources
canalization
nursery area

Within the coastal zone of the Gulf of Mexico two important processes are happening with regard to habitat degradation. First, is the physical loss of habitat generally through erosion. The second is the general reduced quality of habitat generally because of deteriorated water quality.

Since the Gulf of Mexico and its coastal areas are rich in natural resources, an industry will evolve to exploit the resources. Therefore, there is a compound problem of getting to the resource, getting the resource out, and supporting the people to do it. The largest industries are mineral extraction and fishing—both activities occur in the fragile coastal zone. Many parts of the Gulf of Mexico coast that are not industrial in nature are pristine areas developed as tourist attractions. Though in places tourism and industry can be found side by side. The tourist attractions draw in millions of visitors each year as well as an increase in permanent year round residents. People need space, freshwater, and a service industry to support their other needs such as food, recreation, etc. Military activities in the Gulf of Mexico also account for coastal land usage. There are several naval and air force bases along the U.S. Gulf of Mexico.

There are numerous examples of habitat loss along the Gulf of Mexico. The erosion of barrier islands and shorelines has destroyed shorebird nesting grounds and seaturtle nesting habitat. Barrier islands erode because of natural processes and human interference. Barrier islands are some of the prime tourist attractions in the Gulf of Mexico making their real estate extremely valuable. Barrier islands have the important function as first line storm defense (see section on barrier islands) making them valuable to inland marshes and human habitation. Hurricane Andrew hit the Louisiana coast with 140 mph winds, but damage was minimal because of abatement by coastal marshes.

There has been tremendous loss of seagrass beds because of increased turbidity of the coastal waters by nutrient enrichment and increased amounts of sediments due to urban runoff and dredging. This is especially apparent in the Tampa Bay area where there has been an 80% loss of seagrass beds. Seagrass beds are nursery areas for fish and shellfish. In Louisiana coastal wetlands are being lost at a rate of 25-32 square miles per year (approximately one acre every 30 minutes). Some of this loss is natural such as subsidence and some of it directly human induced such as

HUMAN IMPACT

HABITAT DEGRADATION

canalization which may also accelerate natural processes.

The demand for human habitat such as buildings, homes, hotels, parking lots, shopping centers, restaurants, municipal services, and so forth physically remove or destroy natural habitat. The people and industries along the Gulf of Mexico coasts have a high demand for freshwater. Therefore, water tables are dropping very low in some areas and saltwater intrusion into the aquifer is occurring. Marinas and ports for commercial, military, and recreational vessels usually require dredging. Dredging is also done to maintain shipping channels. Dredging increases turbidity and releases toxics and heavy metals that were bound in the sediments adding to reduced water quality.

Coastal development due to industry, fishery resources, military concerns, retirement, and tourism put tremendous pressures on coastal habitats. The types of habitat we are considering are in the table below. There are many different habitats each with a unique and important contribution to the Gulf of Mexico. The human population of the Gulf of Mexico will continue to grow (see population

table). Fragile coastal areas need to be conserved and managed to sustain its many habitats and their important contribution to the Gulf of Mexico marine ecosystem.

Coral reef habitat is also susceptible to human activities. The U.S. government has made the Flower Gardens, a coral reef off the Texas coast, a marine sanctuary. The Department of Interior's Mineral Management Service limits exploration activities near this reef. The anchoring and grounding of boats over reefs is physically damaging. Over exploitation by spearfishing and harvesting of live rock for aquaria is a further concern. Increased turbidity from dredging and land drainage also adversely affects coral. Coral requires clean transparent waters for the symbiotic algae it is commensal with.

The potential for disaster in the Gulf of Mexico is high. The tremendous shipping industry that transports oil, natural gas, chemicals of all kinds, and military operations requires a doubling of safety efforts to avoid habitat destruction.

Totals of Selected Wetlands by state for the Gulf of Mexico

State	Salt Marsh	Fresh Marsh (tidal)	Forested Scrub-Shrub (Estuarine)	Forested Scrub-Shrub (tidal fresh)	Tidal Flats	Total	Percent of total
TX	432,000	22,500	2,600	7,400	275,100	739,600	20
LA	1,722,800	66,000	10,200	4,800	31,800	1,834,600	49
MS	58,800	-	900	-	2,300	62,000	2
AL	25,500	100	2,800	2,00	4,100	34,500	0
FL	257,200	9,800	613,700	18,400	192,900	1,092,00	29
Total	2,496,300	97,400	630,200	32,600	506,200	3,762,700	

HUMAN IMPACT**HABITAT DEGRADATION****Activity****Examine the data**

Examine the habitat table on the previous page.

Make separate pie charts for each habitat.

Describe what differences between the states may account for the different percentages of a particular habitat.

Examine the population graph on page 56.

Estimate the population per shoreline mile for the year 2050 which is close to your retirement time.

Are you going to want to live on the coast? Why? or Why not?

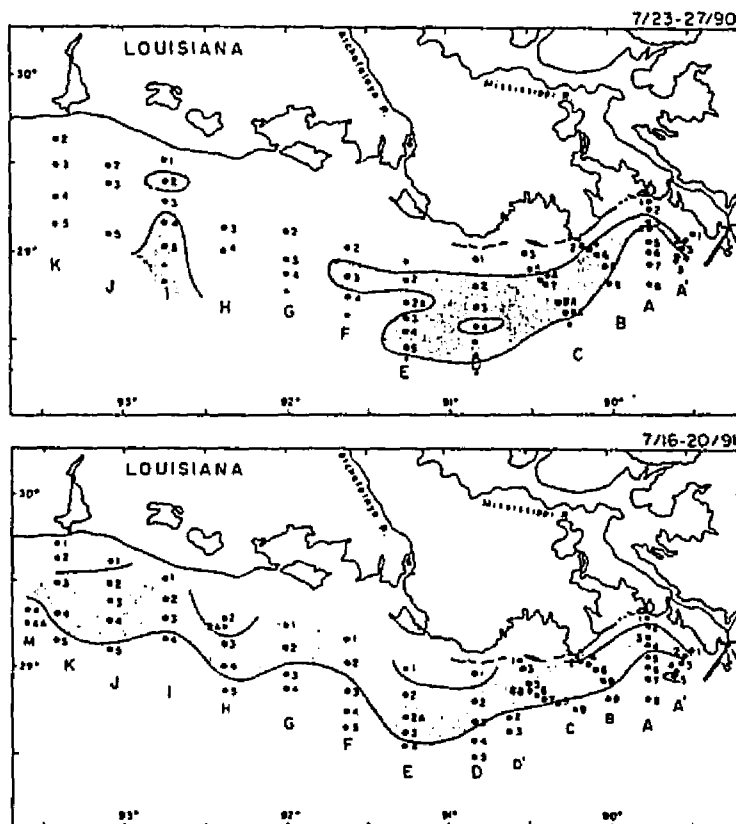
Do you think the coast can sustain this type of growth?

HUMAN IMPACT

DEAD ZONES (HYPOXIA)

Hypoxia on the Louisiana Continental Shelf

1990 and 1991



Modified from Rabalais, N. N., R. E. Turner, and W. J. Wiseman, Jr. 1992. Distribution and characteristics of hypoxia on the Louisiana shelf in 1990 and 1991. In Proceedings of the NOAA Nutrient Enhanced Coastal Ocean Productivity Program Synthesis Workshop, Publ. No. TAMU-SG-92-109, Texas Sea Grant College Program, Texas A&M Univ., College Station.

HUMAN IMPACT

DEAD ZONES (HYPOXIA)

In the news

Floodwater swells Gulf dead zone
Tampa Tribune, Aug. 04, 1993

Flood doubles fish dead zone
Times Picayune, Aug. 8, 1993

Concepts:

hypoxia
dissolved oxygen
nutrients
eutrophication
thermocline

productivity
phytoplankton
continental shelf
diffusion

A temporary phenomena that occurs off the Louisiana and Texas coast during late spring and summer has been given the label dead zones by the newspapers. More properly it is an area of hypoxia or low oxygen. Hypoxia is where there is less than 2 mg/l of oxygen present, a level which is lethal to most living organisms. Hypoxia is the result of chemical, biological, and physical reactions. Not only is this a sign, signal, or symptom of deteriorating environmental conditions in the Gulf, it means there are large areas that are not productive. The Gulf of Mexico, especially the coastal waters, is extremely productive. This phenomena reduces the Gulf's potential productivity.

Nutrient loading from rivers such as the Mississippi River as well as the Atchafalaya River is a normal phenomena and helps explain some of the abundant natural productivity that occurs on our continental shelf. However, in the spring a large pulse of nutrients (nitrates and phosphates) makes its way into the Gulf. The increase in river volume and flow due to spring thawing of accumulated snow and ice from the interior U.S., agricultural use of fertilizers, agricultural waste, municipal waste, forestry practices, atmospheric deposition, runoff from golf courses, industrial discharge, and suburban lawn maintenance all contribute

to this excessive nutrient load. These nutrients also act as fertilizers to the phytoplankton crop in coastal waters, thus enhancing phytoplankton productivity in terms of numbers and biomass. Phytoplankton complete their life cycle in hours to days. As they die and sink towards the bottom of the ocean, they are colonized by heterotrophic bacteria as part of the natural decay processes. These bacteria consume all of the available oxygen in their vicinity. This aspect of excessive nutrient loading is called eutrophication.

It would seem that phytoplankton production of oxygen and diffusion from the land sea interface would replenish the oxygen lost during eutrophication. Replenishment or recharging of the oxygen is stopped by natural density boundaries that form in oceans due to salinity and temperature differences. The ocean water actually becomes stratified. Summertime temperatures and increased sunlight warm the surface waters of the Gulf forming a strong thermocline acting as a density barrier between surface and bottom water masses. Fresh riverine water is less dense than salt water and flows along the surface of the Gulf. The density difference between freshwater and saltwater adds strength to existing stratification. This system drifts west

HUMAN IMPACT

DEAD ZONES (HYPOXIA)

towards Texas due to prevailing easterly winds. The density barriers are broken down by fall winds and decreased river flow into the Gulf.

Most fish and shellfish such as shrimp and crabs have the ability to swim away from hypoxic areas. However, many benthic (bottom-dwelling) organisms such as brittle stars, marine worms, or bivalves are trapped and many die or are extremely stressed. When such a zone moves into coastal waters the animals cannot escape and may be forced on shore. This phenomena may explain occasional "jubilees" where large numbers of fish, shrimp, and crabs can be caught literally on the beach as these animals attempt to find oxygenated waters.

Activity

Who is in charge here?

What states, government agencies, and other interest would have to come together to try to solve the problem of excessive nutrient loading of the Mississippi River?

If you could form a Mississippi River Authority for the sole purpose of limiting nutrient loading of the river, how would you go about doing it?

Compare dead zones over time.

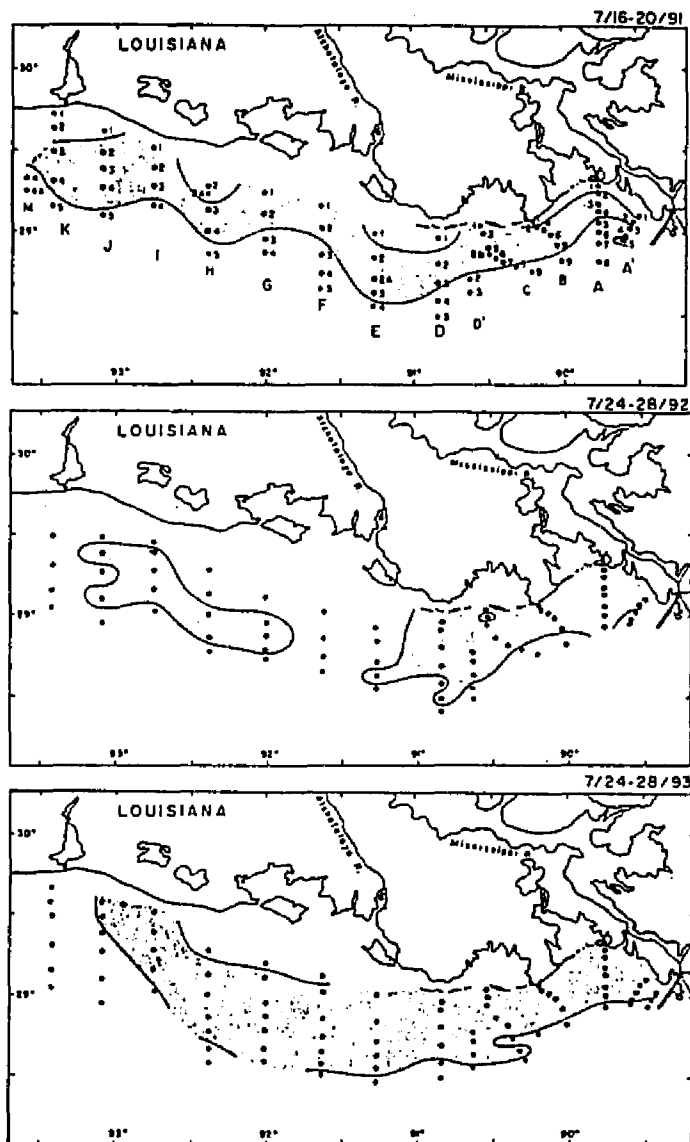
From the graphic on page 65, examine the relative area of hypoxia for 1991, 1992, and 1993.

Research data on the amount of rainfall in the Mississippi River drainage area during those same years.

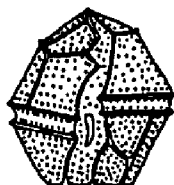
See activity for Water in the Gulf.

HUMAN IMPACT

DEAD ZONES (HYPOXIA)



Areas of hypoxia 1991, 1992, and 1993. Adapted from Rabalais *et al.* (1994, p. 52-53)

HUMAN IMPACT**RED TIDE**

Red Tide Causing Dinoflagellates
Sizes range from 50 - 100 microns (μm)
 $1 \mu\text{m} = 10^{-3} \text{ mm}$

HUMAN IMPACT

RED TIDE

In the news

Red tide cited in 2 fish kills seen offshore
Tampa Tribune, Oct. 6, 1988

Scientists zero in on brown tide cause
Corpus Christi Caller, July 9, 1992

Concepts:

red tide
dinoflagellates
nutrients
filter feeder

phytoplankton
toxin
bloom

Red tide or brown tide is a phenomena associated with a phytoplankton bloom. A phytoplankton bloom is a rapid increase in numbers as well as biomass of phytoplankton, in this case dinoflagellates. Some phytoplankton species of dinoflagellates produce noxious or toxic material. Therefore, a large increase in their number also means a large increase in these substances. Red tides or brown tides (blooms) are thought to be triggered by an excess of nutrients (nitrogen and phosphorus). However, winds, currents, upwelling, and land runoff are also thought to be factors. There doesn't seem to be any way at this time to predict the occurrence of a red tide.

The effects of red tides vary. One effect is fish kills due to the toxins. These fish kills may also be attributable to the eutrophication caused by the phytoplankton bloom. Where red tides occur nearshore local residents may experience respiratory problems, eye irritation, and allergic responses. Filter feeders such as mussels, clams, and oysters may accumulate the toxins of red tide dinoflagellates through ingestion. When such organisms are eaten by humans the result can be a variety of illnesses, most often gastrointestinal disorders.

A red tide outbreak affects the local businesses especially those that may depend on tourist business. If large fish stocks are affected then a recovery time may be necessary thereby affecting the local fishing industry. Clams and oysters in the area of a red tide are rendered unfit for human consumption. It is interesting to note that this local and temporary disruption in the ecosystem may be connected to a variety of possible causes as far away as a farm practices in the mid-west. This is a complex phenomenon with unpredictable results.

The occurrence of red tides may be another indication of Gulf ecosystem health. It is a symptom of stress or deterioration in environmental quality.

Activity

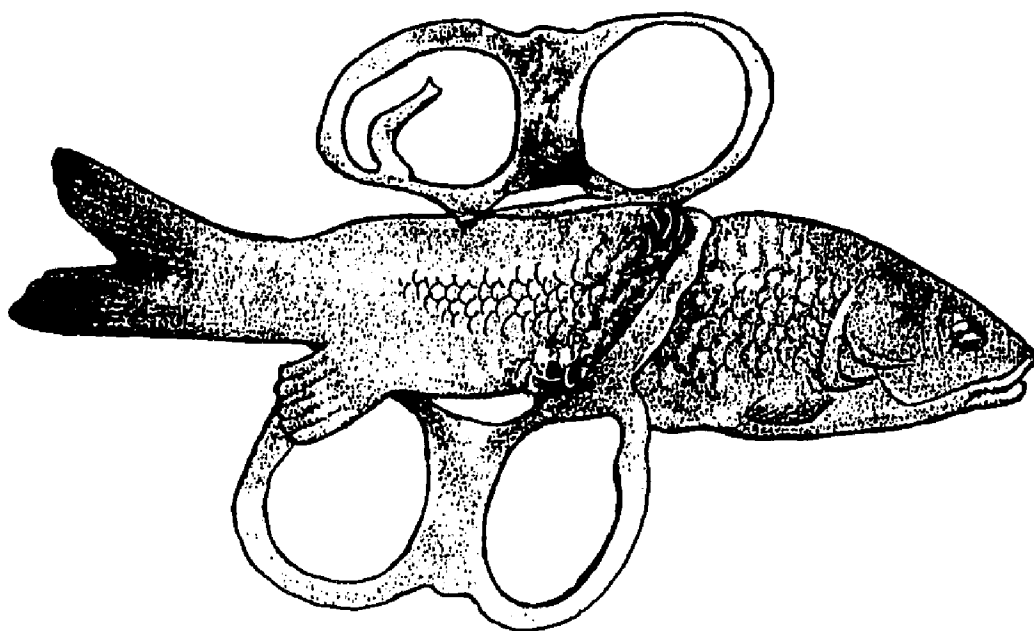
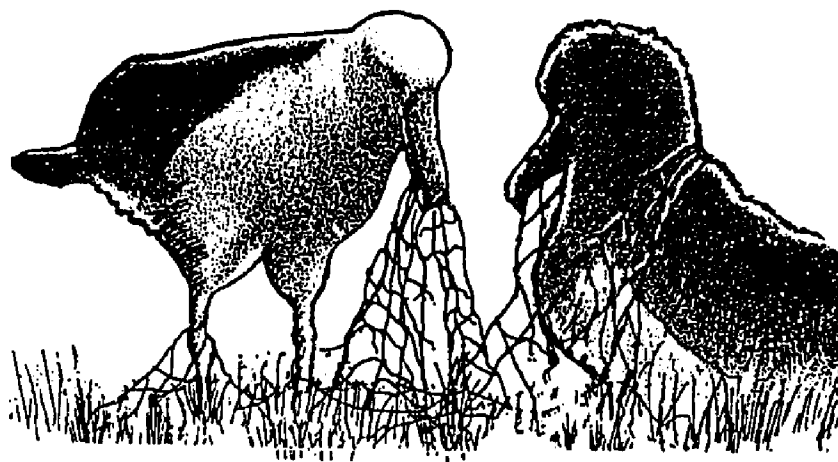
Create an agal bloom

Fill two gallon size jars with water and set them by a window where they get equal amounts of light. In each jar put in a few tables spoons of pond scum.

After 5 days place a table spoon of liquid plant fertilizer in one of the jars. In a few days there should see a visible difference in the amount of agal growth between the two jars.

HUMAN IMPACT

MARINE DEBRIS



HUMAN IMPACT

MARINE DEBRIS

In the news

Thousands join in area cleanups of beaches, rivers
Tampa Tribune, Apr. 26, 1992

Volunteers flock to beaches to get trash out of splash
Mobile Register, Sept. 20, 1992

Concepts:
marine debris
plastics
endangered species
ghost fishing

ingestion
entanglement
seaturtles

Thousands of tons of trash and garbage are dumped into the Gulf each year. The sources are many, but include the Gulf's fishing fleet, cruise ships, recreational boats, offshore oil and gas industry, people who litter on the beaches and coastal areas, and military vessels. A percentage of the solid waste that enters the Gulf is from land runoff. The persistent form of this waste is plastic, glass, and rubber materials. These materials do not deteriorate quickly and a lot of it floats because of its construction such as bottle forms. Metal, wood, and paper trash are frequent debris items.

Two major problems are associated with plastics in the marine environment are ingestion and entanglement. Many marine animals mistake plastic material for food and consume it. Endangered seaturtles consume jellyfish and a plastic bag floating in the water resembles a jellyfish and is consumed. Styrofoam beads and plastic pellets resemble fish eggs and are consumed. The plastic will make an animal stop eating because it feels full or will block the intestines and stomach causing death.

Animals get tangled in plastic material especially fishing line, netting, and six-pack holders. Once an animal is tangled, they may not be able to perform tasks such as eating or movement. Some

animals are strangled or suffocate. Another complication from being tangled is once free of the material a wound may be present that could lead to infection. It is estimated that 2 million seabirds and 100,000 marine mammals die each year from entanglement or ingestion of marine debris (EPA, 1992).

Discarded or lost netting material does not stop catching fish. Such netting may roll around the ocean floor trapping fish and invertebrates. Other fish and sharks may be attracted to the net because of the available food caught in the net. This is known as "ghost fishing." In a similar manner lost traps such as crab traps continue to catch organisms that are never harvested, but die and rot in the trap. Marine debris can be a human safety hazard if people get cut on metal or glass. This material is also a hazard to recreational boaters if their props get caught in this material or it gets sucked into the water cooling system.

Marine debris finds its way to Gulf beaches averaging up to a ton a mile in some areas. It is unsightly and may discourage tourists, but from an environmental perspective it becomes a danger to shore birds. Each fall thousands of volunteers go to the beaches to pick up garbage and trash. While

HUMAN IMPACT

MARINE DEBRIS

viewed as extremely successful program generating interesting statistics about the trash and its sources, it must be realized that beaches are just catching a small portion of the trash in the Gulf and this debris should be viewed as a symptom of a larger problem.

Steps have been taken to reduce this problem through international agreements, federal, and local legislation. Government agencies such as NOAA (National Oceanic and Atmospheric Administration), EPA (Environmental Protection Agency), Coast Guard, and Department of Interior are taken steps to deal with this problem. Conservation agencies like the Center for Marine Conservation spearhead annual beach sweeps and involve industry and local governments in cooperative efforts. Adoption programs also seem to be growing. This is where a group adopts a beach, stream, river, or wetland and keeps it clean.

Individuals can get involved by supporting the passage of laws that will help reduce disposal of materials or littering. The annual beach sweeps are always looking for volunteers. Recreational boaters and beach goers can carry their refuse home with them. You can reduce the amount of solid waste by reducing, reusing, and recycling solid materials.

In 1988 the Center for Marine Conservation began ranking the items most collected and reported by cleanup volunteers. The top 12 items of those listed below are known as the dirty dozen:

- cigarette filters
- plastic pieces
- foamed plastic pieces
- plastic caps and lids
- plastic bags and wrappers
- plastic cups, utensils, and straws
- glass beverage bottles
- metal beverage cans

- paper pieces
- foamed plastic cups
- glass pieces
- plastic rope
- plastic beverage bottles
- metal bottle caps
- miscellaneous plastic bottles

Activity

What is the trash total?

Total the numbers for each category from the 1991 beach cleanup results. Make a histogram comparing the totals from each group. Note: Totals are by numbers not by weight.

Is some of this material recyclable?

Is there anything unusual on the list?

What can you do, even if living far from the coast, about marine debris?

Personal action

Do you know someone who has participated in a beach sweep? Ask them what they saw? What kind of debris did they see? If they have gone more than one year were there any differences?

During September participate in a beach sweep.

If you live close to a beach, start an adopt-a-beach program.

HUMAN IMPACT

MARINE DEBRIS

1991 Beach Cleanup Results



PLASTIC

Bags	347,263
Bottles	240,143
Buckets	10,335
Buoys	16,086
Caps/lids	212,852
Cigarette butts	940,430
Cigarette lighters	34,501
Cups/utensils	
Hard plastic	128,597
Foamed plastic	125,008
Diapers	12,686
Egg cartons	8,605
Fast-food containers	31,856
Fishing line	36,124
Fishing nets	9,496
Floats/lures	13,381
Foamed plastic packaging	44,025
Foamed plastic plates	23,729
Hard hats	1,777
Light sticks	16,020
Meat trays	16,532
Pieces	
Hard plastic	344,268
Foamed plastic	289,802
Pipe thread protector	8,033
Rope	88,862
Sheeting	19,750
Six-pack holders	34,492
Strapping bands	22,512
Straws	191,401
Syringes	8,280
Toys	21,770
Vegetable sacks	7,336
Wrist protection rings	9,148
Other	149,106

TOTAL =

GLASS

Bottles	235,224
Fluorescent light tubes	4,561
Light bulbs	11,766
Pieces	219,468
Other	24,064

TOTAL =

RUBBER

Balloons	36,164
Gloves	11,238
Tires	8,069
Other	43,408

TOTAL =

METAL

Bottle caps	106,626
Cans	237,287
Crab/fish traps	3,795
55-gallon drums	4,587
Pieces	41,204
Beverage can pull tabs	48,670
Wire	17,535
Other	44,358

TOTAL =

PAPER

Bags	38,427
Cardboard	33,450
Cartons	24,727
Cups	46,746
Newspapers	26,393
Pieces	225,297
Plates	21,235
Other	56,436

TOTAL =

WOOD

Crab/lobster traps	7,254
Crates	2,811
Lumber	76,830
Pallets	4,293
Other	31,196

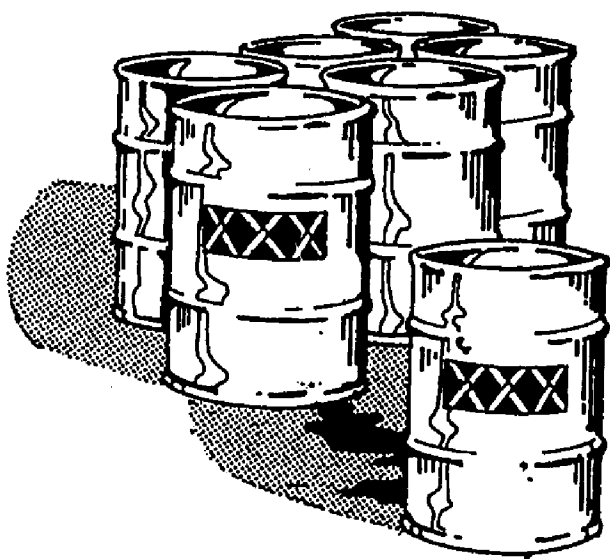
TOTAL =

CLOTH

Clothing pieces	53,405
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TOTAL =

Data were taken from *Cleaning North America's Beaches: 1991 Beach Cleanup Results*. Center for Marine Conservation, 1992.

HUMAN IMPACT**WATER POLLUTION**

HUMAN IMPACT

WATER POLLUTION

In the news

Chemicals settle under bay's waters
Mobile Register, Dec. 19, 1993

DEQ: Wetlands contaminated by toxic waste
Times Picayune, Sept. 7, 1992

Concepts:

point source
bioaccumulation
pollutants
phytoplankton

non-point source
toxics
nutrients
bloom

There is considerable dumping of material into streams, bayous, bays, and rivers that lead to the Gulf of Mexico as well as direct dumping into the Gulf of Mexico. Most major rivers have a number of industrial plants along their banks. These industries need a source of freshwater for their manufacturing processes as well as a place to discharge waste products. A large number of petrochemical industries are associated with the Mississippi River between Baton Rouge and New Orleans as well Houston, Corpus Christi, and Mobile. In Mexico, Tampico and Coatzacoalcos have a large number of such industries. Other sources of pollutants into the Gulf of Mexico are agricultural, municipal, accidental spills, shipping, and atmospheric deposition.

Sources like the petrochemical industry are called point source pollution because the exact source of discharge can be located (e.g., a pipe). Other sources of pollutants are less obvious and harder to locate. These are known as non-point sources of pollution. For example, what comes out of a storm drain is the accumulation of material and runoff from that drainage area which may include a housing subdivision, a shopping center, and the corner gas station. Municipalities dump more than a billion gallons a day of sewage effluent into Gulf waters. Therefore, it is hard to locate the exact point source of a pollutant. Sources of

pathogenic bacteria particularly *Escherichia coli* are hard to locate if a group of homes are on septic tanks and in the vicinity of large mammals (livestock). Is it one tank that is not working properly or more? Modern agriculture practices that include application of fertilizers, herbicides, and pesticides also contribute to non-point source water pollution. When excessive amounts of nutrients enter the Gulf, phytoplankton blooms occur that are implicated in dead zones and red tide occurrences.

Home owners often use similar chemicals as farmers, but in smaller amounts. However, when multiplied by the number of possible users it is a significant amount. Used motor oil is often poured down storm drains without thought of its final destination. Dredged materials are dumped into the Gulf at a rate of 100 million tons every year. The dredged materials sometimes contain heavy metals and other chemicals that were accumulated over time (see habitat degradation). The offshore oil industry contributes drilling muds, lubricants, galley waste, and other chemical used to drill for oil and natural gas.

Other toxic material may accumulate in the sediments and are then consumed by benthic or bottom dwelling organisms. In that manner the toxins are

HUMAN IMPACT

WATER POLLUTION

bioaccumulated further up the food chain. The DDT story is a classic example. DDT, a pesticide, had broad application and use in the U.S. It was effective at eradicating mosquitoes, so you can imagine how much of it was used along the Gulf coastal areas. Throughout the process of bioaccumulation, pelicans, eagles, and other fish eating birds were getting larger dosages. It is simple math. If a fish has x amount of DDT in its body and a pelican eats 5 fish a day, then the pelican is getting 5 times (5X) the amount of DDT per day. DDT affected these birds by causing them to lay eggs with very thin shells, so there was a high nesting mortality. Populations then started to decline because less birds were being added to the existing population. As you can see, animals and plants that live in the estuaries, waterways, and coastal waters of the Gulf are tied very closely to water quality.

fertilizers
pesticides
herbicides

How is it disposed of?

How should it be disposed of?

Trace the path of your storm drain, sewer system, septic tank to nearest stream, river, or lake.

With the large shipping industry in the Gulf of Mexico, potential for accidental spills must be considered. Several major oil spills have occurred in the Gulf such as the Mega Borg. We must also consider that there are also many ships and barges loaded with chemicals and toxic materials operating in the Gulf.

Activity

Home checklist

Check and see if you use any of the below products or practices at your home.

bleaches
detergents
solvents
paint thinners
ammonia products
gasoline
motor oil
kerosene
antifreeze and coolant

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APPENDIX C
CONCEPT MAPS OF GULF LITERACY

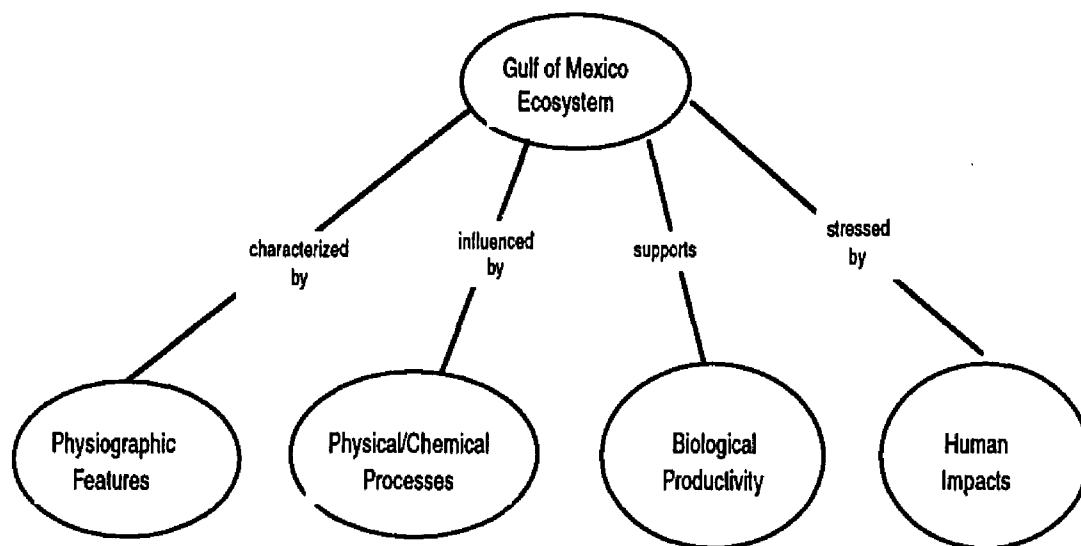


Figure C1. Concept map showing four conceptual organizers.

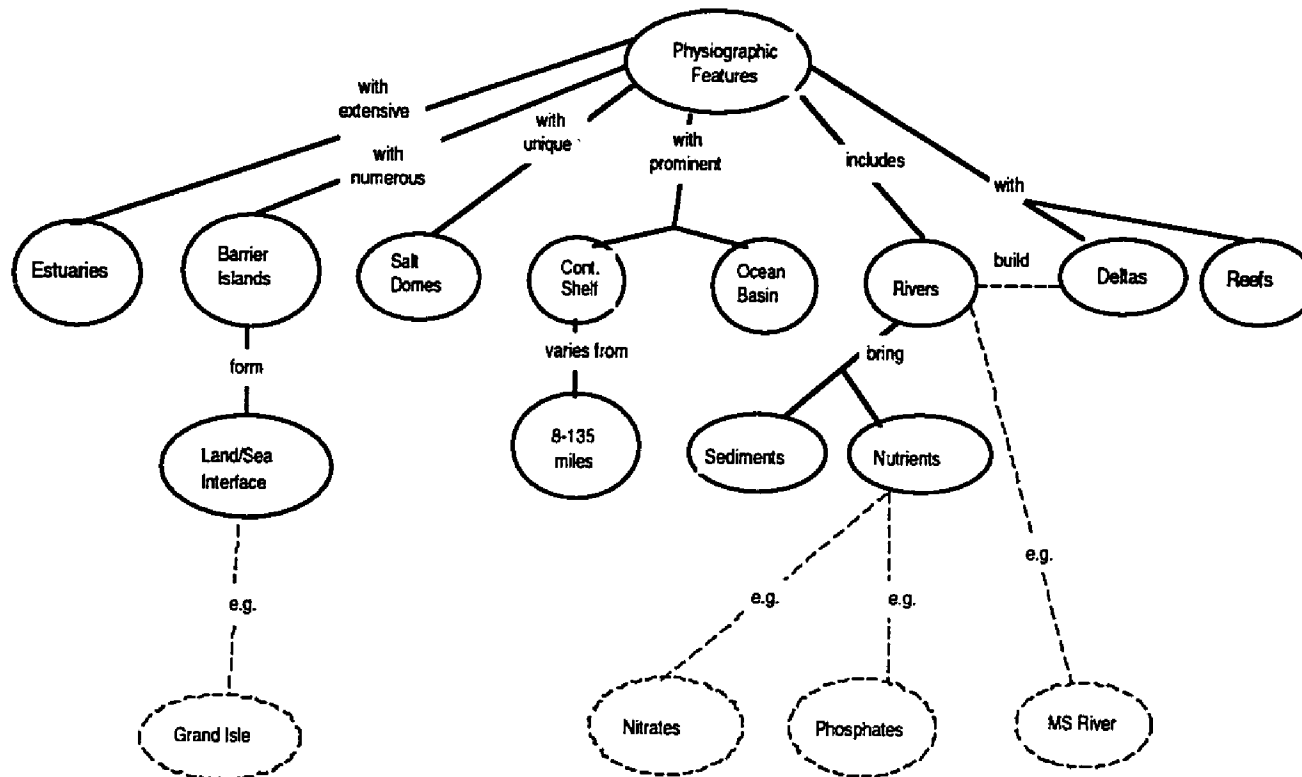


Figure C2. Concept map of physiographic features.

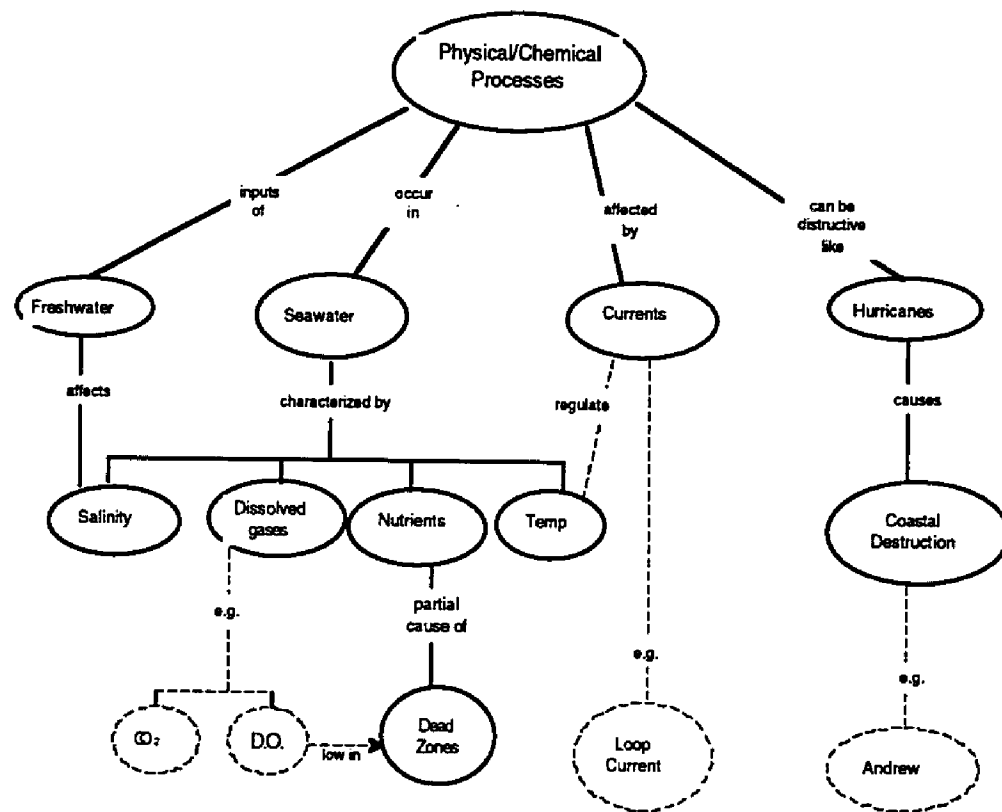


Figure C3. Concept map of physical/chemical processes.

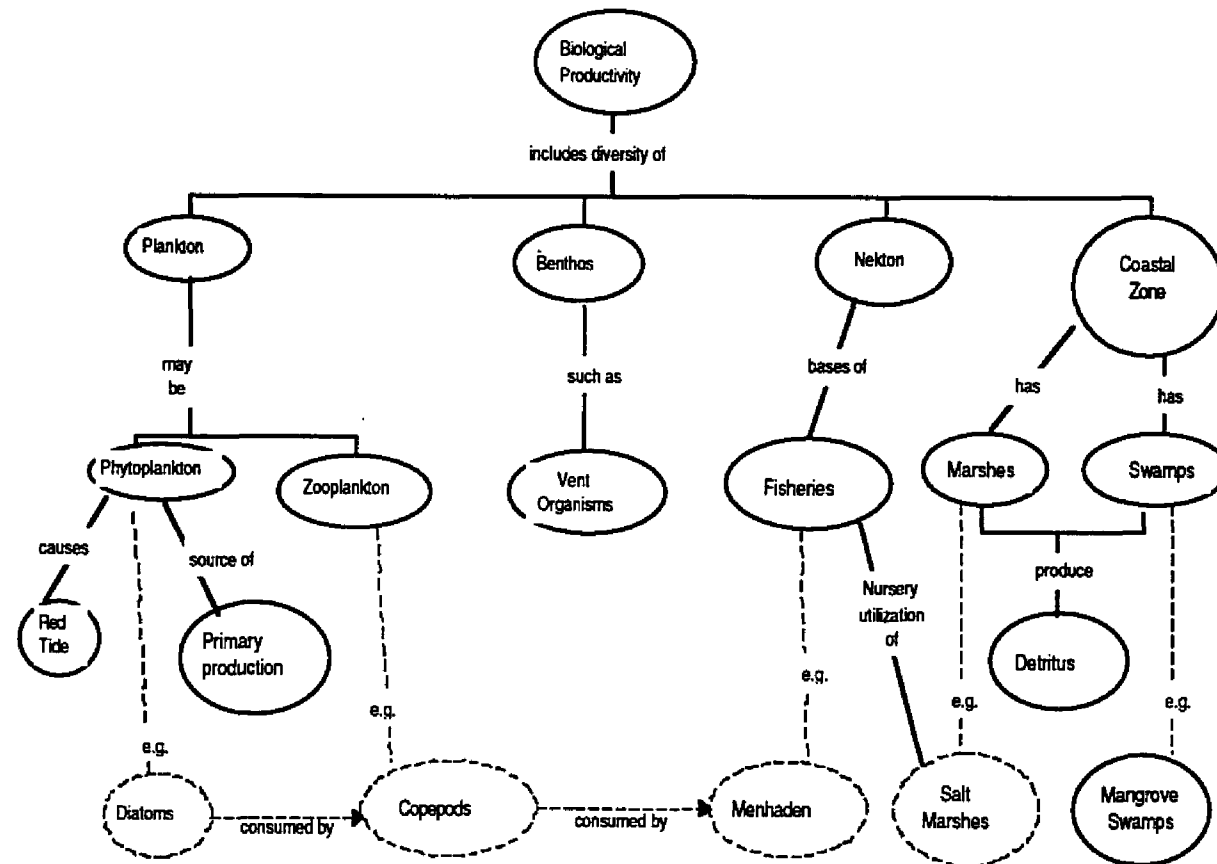


Figure C4. Concept map of biological productivity.

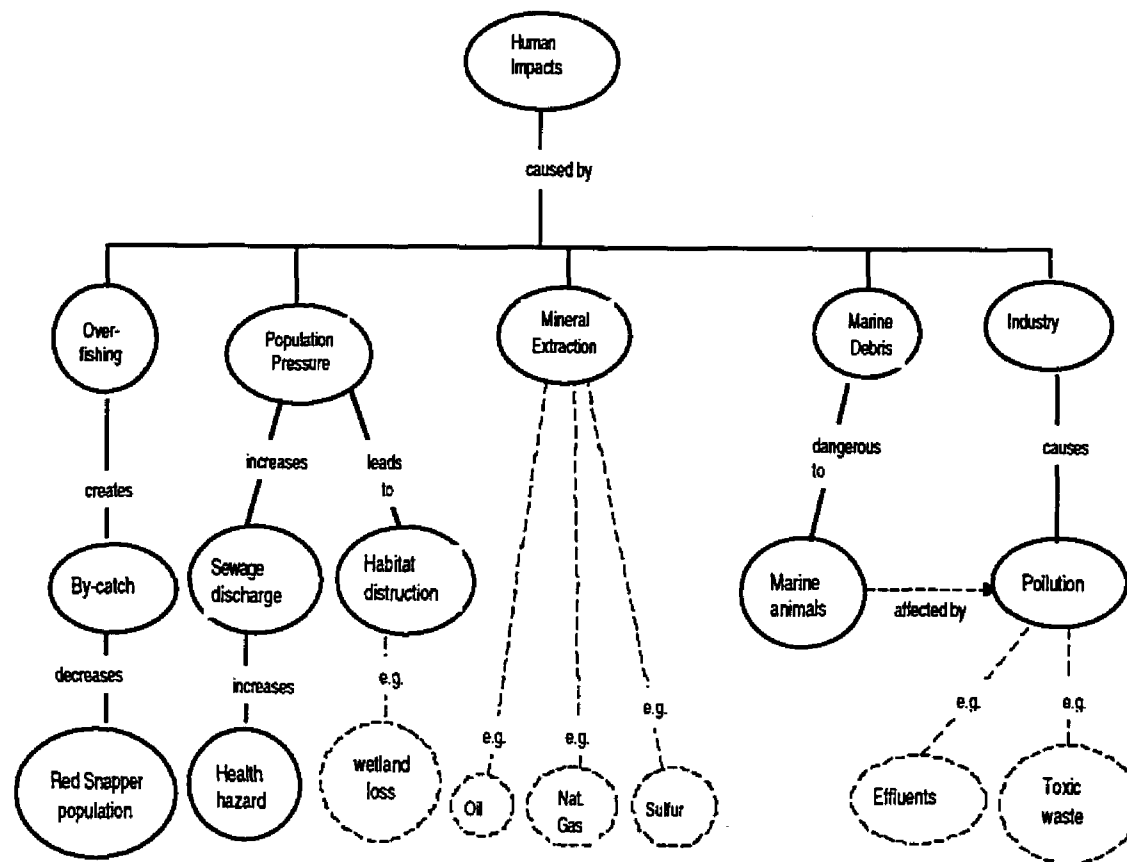


Figure C5. Concept map of human impacts.

APPENDIX D
QUESTIONNIARE

Gulf of Mexico Questionnaire

Name _____

1. List 4 significant physiographic (physical) features of the Gulf of Mexico.

a. _____

b. _____

c. _____

d. _____

2. Explain dead zones and why they occur.

3. What are two sources of land based nutrients?

a. _____

b. _____

4. Are plankton beneficial, detrimental, or neutral in the Gulf ecosystem?
Explain.

5. Do barrier islands serve any function other than as a tourist attraction?
If so, what?

6. Why are several species of fish and shellfish dependent on estuaries?

7. Why is marine debris a problem in the Gulf of Mexico?

8. What are two things that concern you about the Gulf of Mexico?

a. _____

b. _____

9. If you could make a law or regulation concerning the Gulf of Mexico,
what would it be?

10. If a major environmental problem related to the Gulf of Mexico could be solved by the use of volunteer labor, would you volunteer your time? If so, how much time?

11. List 5 things you want to know more about related to the Gulf Of Mexico.

a. _____

b. _____

c. _____

d. _____

e. _____

12. Can you list or describe any graphics from the unit on the Gulf of Mexico that you thought were especially interesting or helpful? Please tell why?

13. Are coastal residents completely safe from hurricanes now because of modern forecasting? Why or why not?

Please Answer the following by circling the appropriate number.

1= strongly disagree, 5= strongly agree.

14. I have a personal connection to the Gulf of Mexico.	1	2	3	4	5
15. What I do in Hammond has no affect on the Gulf.	1	2	3	4	5
16. I will try to stay current on issues related to the Gulf.	1	2	3	4	5
17. There is no connection between habitat degradation and fisheries production.	1	2	3	4	5
18. Graphics such as pictures, charts, and drawings help me learn concepts.	1	2	3	4	5
19. I would like to join a club or organization that tries to protect the resources and environment of the Gulf.	1	2	3	4	5
20. People should take a larger role in managing the environment and resources of the Gulf.	1	2	3	4	5
21. The government at all levels seems to be doing a good job in managing the Gulf's resources and environment.	1	2	3	4	5
22. Freshwater flow into the Gulf of Mexico is mainly from the Mississippi River.	1	2	3	4	5

23. Scientists can easily predict a "red tide."	1	2	3	4	5
24. Water can actual stratify based upon differences in salinity and temperature.	1	2	3	4	5
25. Salt domes form over the course of thousands of years.	1	2	3	4	5
26. The origin of the Gulf Stream is in the Gulf of Mexico.	1	2	3	4	5

What do the following terms mean to you. Associate the term and your meaning to other significant concept(s) related to the Gulf of Mexico. Underline the other significant concepts in your description of the term.

Example term:

menhaden - Menhaden are fish that constitute the largest commercial fishery in the Gulf. We do eat them. They are processed into a fish meal. It is not a managed species.

Terms:

bycatch -

TEDs -

manatee -

nursery area -

productivity -

non-point source pollution -

APPENDIX E
QUESTIONNAIRE RESPONSES

Table E1
Top Ten Physical Features Of The Gulf Of Mexico Listed By Students

<u>Urban M. H. (n=25)</u>			<u>Suburban M. H. (n=29)</u>			<u>Rural H. (n=18)</u>			<u>Small Town H. (n=22)</u>			<u>All (N=94)</u>		
Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	% of N
Barrier Islands	18	72	Saltwater	23	79	Water	8	44	Barrier islands	13	59	Barrier islands	39	41
Estuaries	17	68	Oval shaped	16	55	Estuaries	5	28	Estuaries	12	55	Estuaries	34	36
Salt domes	16	64	600,00 sq. mi.	12	41	Salt domes	3	17	Cont. shelves	9	41	Saltwater	32	34
Rivers	16	64	5,000 ft av.	12	41	Barrier islands	3	17	Saltwater	5	23	Rivers	22	23
Coral Reefs	4	16	Input of water	6	21	Storms	3	17	Rivers	5	23	Salt domes	22	23
Saltwater	3	12	Marshes	6	21	Land	3	17	Coasts	4	18	Oval shaped	17	18
Continental Shelf	3	12	Storms	5	17	Basin	3	17	Whales	4	18	Cont. shelves	13	14
Semi-enclosed by land	3	12	Currents	5	17	Animals	2	11	Salt domes	3	14	Water	12	13
Surrounding land	1	4	Barrier islands	5	17	Reefs	2	11	Dunes	2	9	5,000 ft. av. depth	12	13
Empties into Atlantic	1	4	Marine animals	5	17	Marshes	2	11	Basins	2	9	600,000 sq. mi.	12	13

Table E2
Response Categories To Dead Zone Explanations

Response category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>Small Town H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Describes phenomenon	3	12	1	3	1	6	3	14	8	9
2. Emergent-includes low O ₂	5	20	17	59	4	22	2	9	28	30
3. Poor-associates with death	9	36	1	3	3	17	5	23	18	19
4. No understanding demonstrated	4	16	9	31	6	33	8	36	27	29
5. No response	4	16	1	3	4	22	4	18	13	14

Table E3
Sources Of Land Based Nutrients

<u>Urban M. H.</u> response	No.	%	<u>Suburban M. H.</u> response	No.	%	<u>Rural H.</u> response	No.	%	<u>Small Town H.</u> response	No.	%	<u>All</u> Response	No.	%
Rivers	8	32	Oil	18	62	Trees	4	22	Rivers	4	18	Rivers	13	14
Sediment	7	28	Sulfur	16	55	People along Gulf	3	17	Dissolved CO ₂	4	14	Sediment	10	11
Plants	4	16	Natural gas	13	45	Plants	2	11	Dissolved O ₂	3	9	Plants	8	9
Phosphates	3	12	Wetlands	3	10	Soil	1	6	Sediments	2	9	Estuaries	7	7
Salt domes	3	12	Salt domes	3	10	Sand	1	6	Estuaries	2	9	Salt domes	6	6

Table E4
Responses To "Are Plankton Beneficial, Detrimental, Or Neutral?"

school	Ben	%	Ben. & Det.	%	Neutral	%	mention trophic rel. for ben. (%)
Urban M. H.	19	76	4	16	0	0	17 (18)
Suburban M. H.	24	83	1	3	3	10	20 (21)
Rural H.	8	44	1	6	4	22	2 (2)
Small Town H.	8	36	2	9	3	14	3 (3)
Total	59	63	8	9	10	11	42 (45)

Table E5
Responses To "Do Barrier Islands Serve Any Function Other Than As A Tourist Attraction? If So, What?"

<u>Urban M. H.</u> response	No.	%	<u>Suburban M. H.</u> response	No.	%	<u>Rural H.</u> response	No.	%	<u>Small Town H.</u> response	No.	%	<u>All Top 2</u> response	No.	%
Storm protection	22	88	Storm protection	16	55	Slows down erosion	4	22	Storm defense	14	64	Storm protection	52	55
Protect estuaries	4	16	Prevent coastal erosion	7	24	Animal habitat	3	17	Prevent saltwater intrusion	5	23	Coastal protection	19	20
Stop flooding	1	4	Provides nutrients	2	7	Place to live	2	11	Rest & nest for birds	3	14			
Wildlife habitat	1	4	Source of salt domes	1	3	Block wave erosion	1	6	Habitat for animals	3	14			
			For muscels in the water	1	3	Barrier for bays	1	6	Its a physical feature	1	5			
			They are estuaries	1	3	Helps environment	1	6	Barrier to pollution	1	5			
			No	1	3	Supply nutrients	1	6	Nesting spot for sea turtles	1	5			
						Oil	1	6	Keeps things out of Gulf	1	5			
						Boats and barges	1	6	Nursery ground	1	5			
						Place to live	1	6	No	1	5			
						Place to research	1	6						
						No	3	17						
						No answer	1	6						

Table E6
Responses To "Why Are Several Species Of Fish And Shellfish
 Dependent On Estuaries?"

Category	<u>Urban M.H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>Small Town H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%	No.	%
1 Nursery/Reproduction	9	36	1	3	1	6	7	32	18	19
2 Food	3	12	1	3	4	22	2	9	10	11
3 Protection	5	20	1	3	0	0	1	5	7	7
4 Misc.	7	28	24	83	12	67	10	45	53	56
5 Blank	0	0	2	7	1	6	2	9	5	5

Table E7
Responses To Marine Debris Query

Response	Urban M. H.		Response	Suburban M. H.		Response	Rural H.		Response	Small Town H.	
	No.	%		No.	%		No.	%		No.	%
Harms/kills animals	13	52	Harm/kill	18	62	Harm/kill	8	44	Harm/kill	13	59
Eaten by animals	7	28	Can cause dead zones	2	7	Erosion pollution	1	6	Pollutes water	4	18
Entanglement	3	12	Causes pollution	1	3	Looks bad	1	6	Eat it	2	9
Contamination of the Gulf	2	8	Affects life in Gulf	1	3	People littering	1	6	Not covered	2	9
Looks bad	1	4	Replaces sediments	1	3	Litters beach	1	6	Gets into water	1	5
Slows growth	1	4	Affects dead zones	1	3	Water becomes cloudy	1	6	Big problem	1	5
It's a pollutant	1	4	Pollutes water	1	3	Animals becoming endangered	1	6	B'c mammals	1	5
When catch shrimp, catch debris	1	4	Affected by pollution	1	3	There is so much of it	1	6	Blank	2	9
Never goes away	1	4	Blank	2	7	Bad pollution	1	6			
Adds up	1	4				Entanglement	1	6			
Blank	1	4				Pollutes water	1	6			
						Cause nutrients to be smothered	1	6			
						Blank	1	6			

Table E8
Responses To "What Are Two Things That Concern You About The Gulf Of Mexico?"

Urban M.H. Responses	No.	%	Suburban M.H. Responses	No.	%	Rural H. Responses	No.	%	Small Town H. Responses	No.	%	All Top 5 Response	No.	%
Pollution	11	44	Pollution	15	52	Pollution	8	44	Pollution	11	50	Pollution	45	48
Erosion	11	44	Erosion	8	28	Erosion	7	39	Marine debris	4	18	Erosion	28	30
Marine debris	6	24	Overfishing	6	21	Storms	3	17	Marine life	4	18	Marine debris	14	15
Storms	3	12	Mineral extraction	2	7	Debris	3	17	Overfishing	3	14	Storms	11	12
Hypoxia	2	8	Storms	2	7	Level of salinity	2	11	Storms	3	14	Overfishing	10	11
Shrimp	2	8	Amt. of debris	1	3	Over population	1	6	Erosion	2	9			
Toxic waste	1	4	Dangerous fishery	1	3	Dead zones	1	6	We mistreat it	1	5			
Litter	1	4	Limited amt. of marine life	1	3	Bycatch	1	6	Not enough people willing to help	1	5			
Keep art. reefs going	1	4	Too much salt water	1	3	Oil spills	1	6	Economic	1	5			
Oil spills	1	4	Water	1	3	Marine mammals	1	6	Oil	1	5			
Oil rigs	1	4	Salt water intrusion	1	3	Economy	1	6	Disease	1	5			
Oysters	1	4	Economic stability	1	3	Oil rigs	1	6	The water	1	5			
Recreation	1	4	Sewage discharge	1	3	Animals	1	6	How it is destroyed	1	5			
Flooding New Orleans	1	4	Dead zones	1	3	Blank	2	11	Phytoplankton	1	5			
Overfishing	1	4	Red tides	1	3				Salinity	1	5			
Economy	1	4	How to keep Gulf clean	1	3				Pressure of the water	1	5			
Animals' habitat	1	4	Habitat destruction	1	3				The food we get from it	1	5			
Disruption of animals' lifestyle	1	4	Fishing	1	3				Deadly plants	1	5			
Loss of estuary	1	4	The salt in it	1	3				Why is it that big	1	5			
Delta loss	1	4	Overflowing	1	3				Where is the Mississippi?	1	5			
Deterioration	1	4	Fishing industry	1	3				Sea species	1	5			
			Cleanness of Gulf	1	3				Saltwater intrusion	1	5			

Table E9
Categories Of Laws And Regulations Students Would Make Concerning The
Gulf Of Mexico

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>Small Town H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Fines & penalties	8	32	4	14	4	22	5	23	21	22
2. Pollution reg.	15	60	9	31	10	56	9	41	43	46
3. Animal protection	7	28	8	28	5	28	6	27	26	28
4. Other	3	12	10	34	4	22	3	14	20	21

Table E10

Amount Of Time A Student Would Volunteer To Solve An Environmental Problem Related To The Gulf Of Mexico.

<u>Urban M. H.</u>			<u>Suburban M. H.</u>			<u>Rural H.</u>			<u>Small Town H.</u>			<u>All</u>		
Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	%
As much time as needed	4	16	As much time as possible	3	10	As much as I could	7	39	As much time as needed	6	27	As much time as needed	14	15
As long as I could	3	12	Weekends	2	7	As much as needed	4	22	As much time as possible	4	18	As much time as possible	15	16
One weekend a month	2	8	1 Day	2	7	Most I can offer	2	11	All my spare time	2	9			
Week	1	4	5 hrs. per week	2	7	A lot	1	6	Not much time	2	9			
As much time as possible	1	4	2 hrs. per week	2	7	My extra time	1	6	Weekend	1	5			
Every other weekend	1	4	Depends	2	7	Once per week	1	6	2 weekends per month	1	5			
Couple of Saturdays	1	4	Once a week	2	7	10 hrs. per day	1	6	1 day per month	1	5			
One day every 2 weeks	1	4	5-10 hrs. week	1	3	No	1	6	5 hrs. per day	1	5			
1-2 days	1	4	Don't know	1	3				10 hrs. per week	1	5			
20 hrs.	1	4	5 hrs.	1	3				2 hrs. per month	1	5			
1-2 hrs. per week	1	4	For marine debris	1	3				Picking up trash-shore	1	5			
5 hrs. per week	1	4	My weekends 10-20 hrs.	1	3									
2 hrs. per week	1	4	Once every quarter	1	3									
On my days off	1	4	2 weekends per month	1	3									
Depending on my schedule	1	4	No	4	14									
Do what I could	1	4	Blank	2	7									

Table E11

Top Ten Responses Of Things Students Want To Know More About Related To The Gulf Of Mexico

<u>Urban M. H.</u>			<u>Suburban M. H.</u>			<u>Rural H.</u>			<u>Small Town H.</u>			<u>All top 5</u>		
Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	%	Response	No.	%
Marine animals	11	44	Marine animals and plants	18	62	Marine animals	9	50	Marine life	10	45	Marine life	48	51
Erosion	9	36	Fishing	9	31	Physical features	7	39	Marine mammals	10	45	Marine mammals	20	21
Natural reefs	9	36	Storms	5	17	Pollution	7	39	Physical features	9	41	Physical features	21	22
Barrier islands	7	28	Dead zones	4	14	Estuaries	4	22	Pollution	5	23	Pollution	17	18
Bottom features	5	20	Physical features	4	14	Salt domes	4	22	Estuaries	5	23	Barrier Islands	14	15
Artificial reefs	5	20	Pollution	4	14	Marine mammals	3	17	The water	5	23			
Marine mammals	5	20	Habitat	4	14	Barrier islands	3	17	Temperatures	4	18			
Fishing industry	4	16	Wetland erosion	3	10	Amt. of salt	3	17	Erosion	4	18			
Storms	4	16	Industry	3	10	Fishing	2	11	Fishing industry	4	18			
Salt domes	4	16	Geo-history	3	10	Geo-history	2	11	Barrier islands	3	14			

Table E12
Graphics Students Found Helpful Or Interesting

Urban M. H.			Suburban M. H.			Rural H.			Small Town H.			All Top 2		
Response	No.	%	Response	No.	%	Responses	No.	%	Responses	No.	%	Responses	No.	%
Concept maps	5	20	Oyster lab(?)	5	17	Concept maps	4	22	Model based on bathymetry	11	50	Bathmetry	16	17
Bathymetric map	5	20	About species in Gulf	2	7	Barrier islands	1	6	Ocean basin	5	23	Concept maps	10	11
Thermocline	3	12	Marsh data chart	2	7	Depth over 2 miles	1	6	Erosion	3	14			
Estuarine utilization	2	8	Oyster diagram	2	7	Ecosystems	1	6	Rivers	1	5			
Listing marine debris	2	8	Concept maps	1	3	Erosion	1	6	Life forms	1	5			
Barrier islands	1	4	Graph of Gulf	1	3	Everything	1	6	Estuary	1	5			
Cover	1	4	Gulf fisheries	1	3	Hurricanes	1	6						
Erosion/landloss	1	4	How dirty Gulf is	1	3	Litter	1	6						
Back cover	1	4	How many things contaminate Gulf	1	3	Map with plains and basins	1	6						
Hurricanes	1	4	Seafood and where it came from	1	3	Section on different animals	1	6						
Rivers	1	4	Size and depth	1	3	Shrimp chart	1	6						
Yes ??	1	4	Oval shape	1	3	Shrimp life cycle	1	6						
Blank	2	8	Shrimp landings	1	3	Blank	4	22						
			Unit on bio productivity	1	3									
			Not readable	1	3									
			Blank	1	3									
			No	4	14									

Table E13

Responses To, "Are Coastal Residents Completely Safe From Hurricanes Now Because Of Modern Forecasting?" And "Why Or Why Not?"

Response	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>Small Town H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Resident's decision	7	28	2	7	2	11	0	0	11	12
2. Mistrust forecast/hur. unpred.	7	28	11	38	14	78	8	36	40	43
3. Lack of evacuation time	4	16	0	0	1	6	0	0	5	5
4. Other	5	20	5	17	5	28	8	36	23	24
5. Yes	2	8	1	3	1	6	6	27	10	11

Table E14
Concept: TEDs

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%
1. Concept developed	12	48	19	66	10	56	41	57
2. Other	1	4	6	21	5	28	12	17
3. Blank	12	48	4	14	3	17	19	26

Table E15
Concept: Nursery Area

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%
1. Concept developed	8	32	2	7	0	0	10	14
2. Concept emergent	8	32	10	34	8	44	26	36
3. Other	2	8	11	38	6	33	19	26
4. Blank	7	28	6	21	4	22	17	24

Table E16
Concept: Productivity

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%
1. Biological	5	20	1	3	6	33	12	17
2. Economic/Nat. Res.	3	12	0	0	0	0	3	4
3. Combined 1&2	4	16	0	0	0	0	4	6
4. Other	6	24	21	72	7	39	34	47
5. Blank	7	28	7	24	5	28	19	26

Table E17
Concept: Nonpoint Source Pollution

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%
1. Concept developed	13	52	13	45	6	33	32	44
2. Not developed	2	8	7	24	6	33	15	21
3. Blank	10	40	9	31	6	33	25	35

Table E18
Concept: Manatee

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>Small Town H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Marine mammal	16	64	7	24	8	44	7	32	38	40
2. Mentioned vulnerable to boats	9	36	6	21	3	17	6	27	24	26
3. Mentioned endangered	3	12	7	24	5	28	5	23	20	21
4. Other	5	20	10	34	2	11	5	23	22	23
5. Blank	1	4	3	10	7	39	2	9	13	14

Table E19
Concept: Bycatch

Category	<u>Urban M. H.</u>		<u>Suburban M. H.</u>		<u>Rural H.</u>		<u>All</u>	
	No.	%	No.	%	No.	%	No.	%
1. Concept developed	8	32	11	38	0	0	19	26
2. Concept emergent	4	16	11	38	10	56	25	35
3. Other	3	12	4	14	2	11	9	13
4. Blank	10	40	3	10	6	33	19	26

APPENDIX F
CONCEPT MAPS

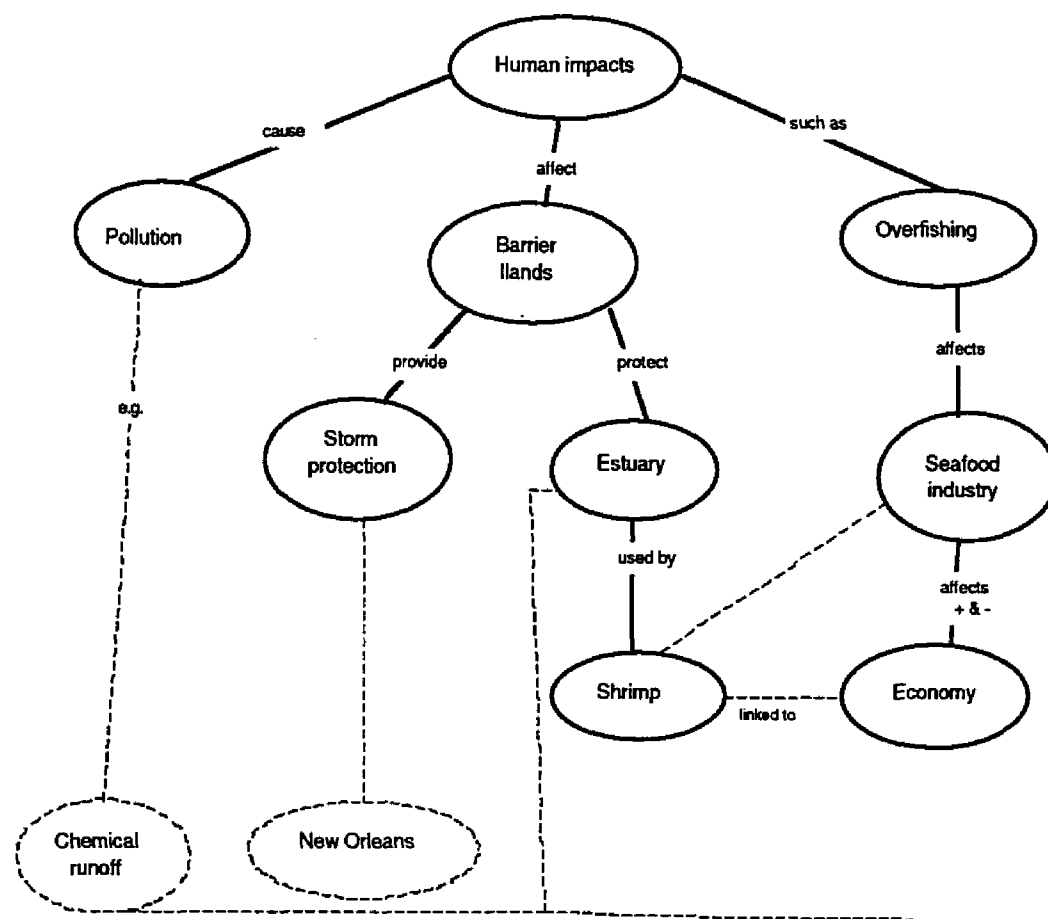


Figure F1.
 Concept map: Ed from Urban Magnet High.

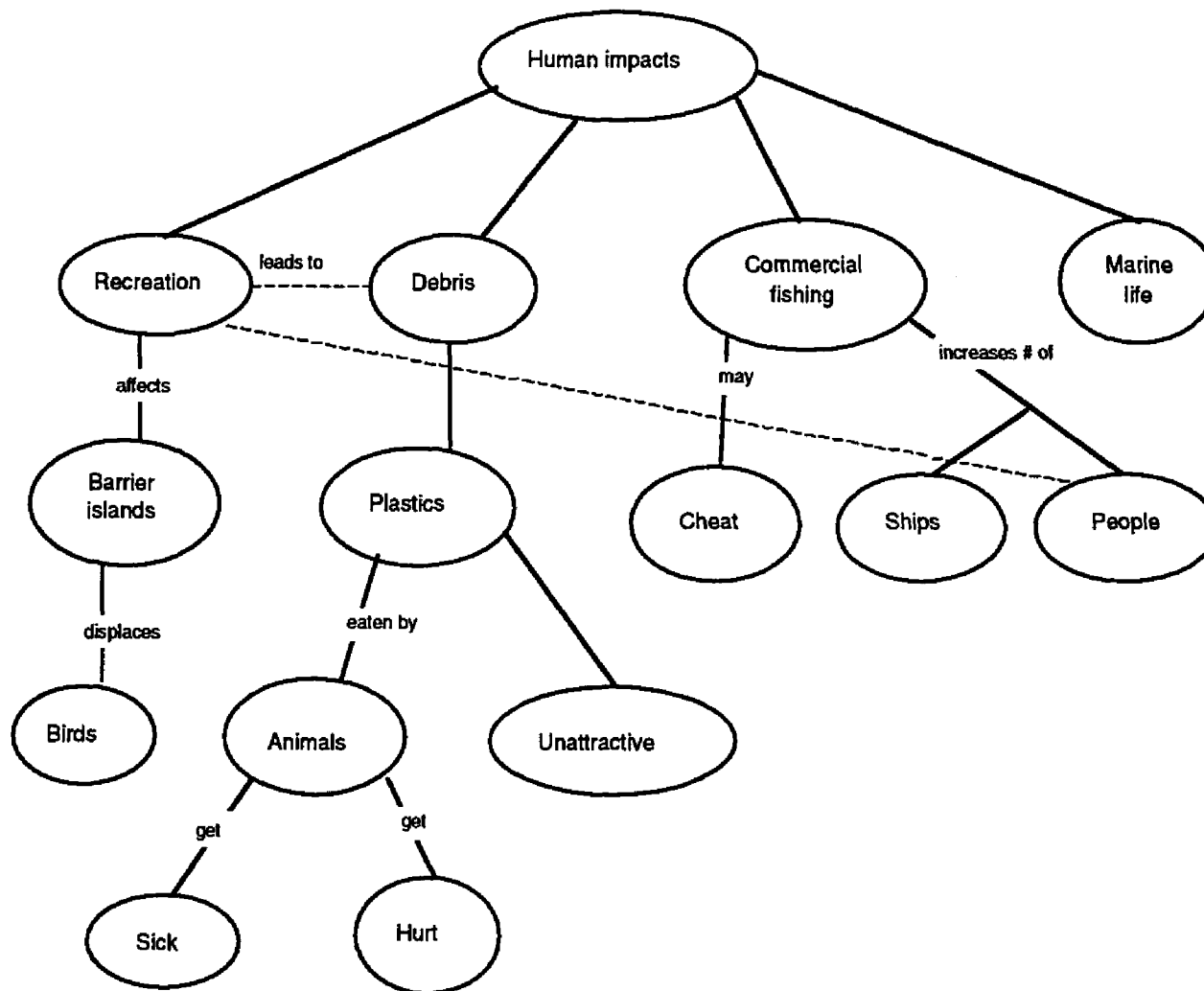


Figure F2.
Concept map: Drew from Urban Magnet High.

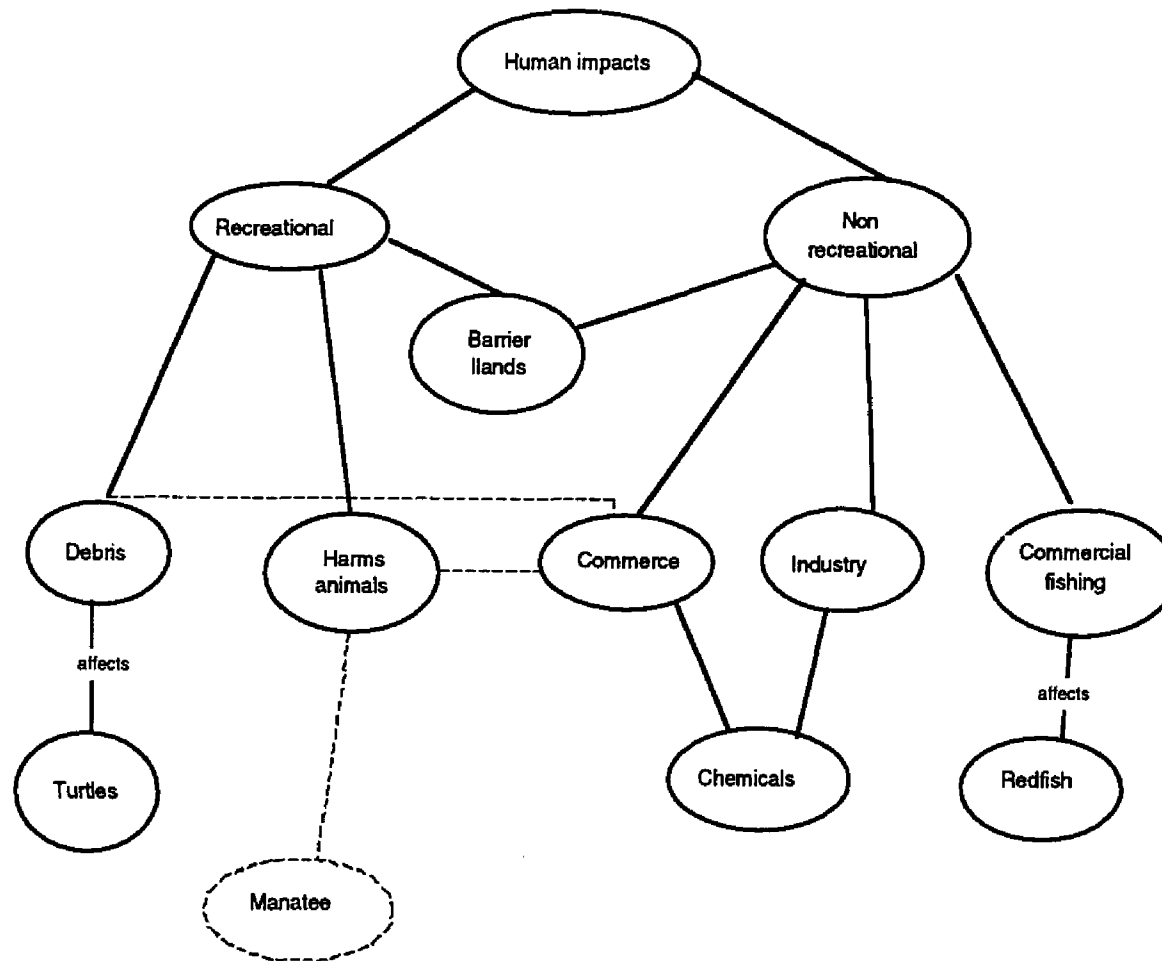


Figure F3.
Concept map: Ron from Urban Magnet High.

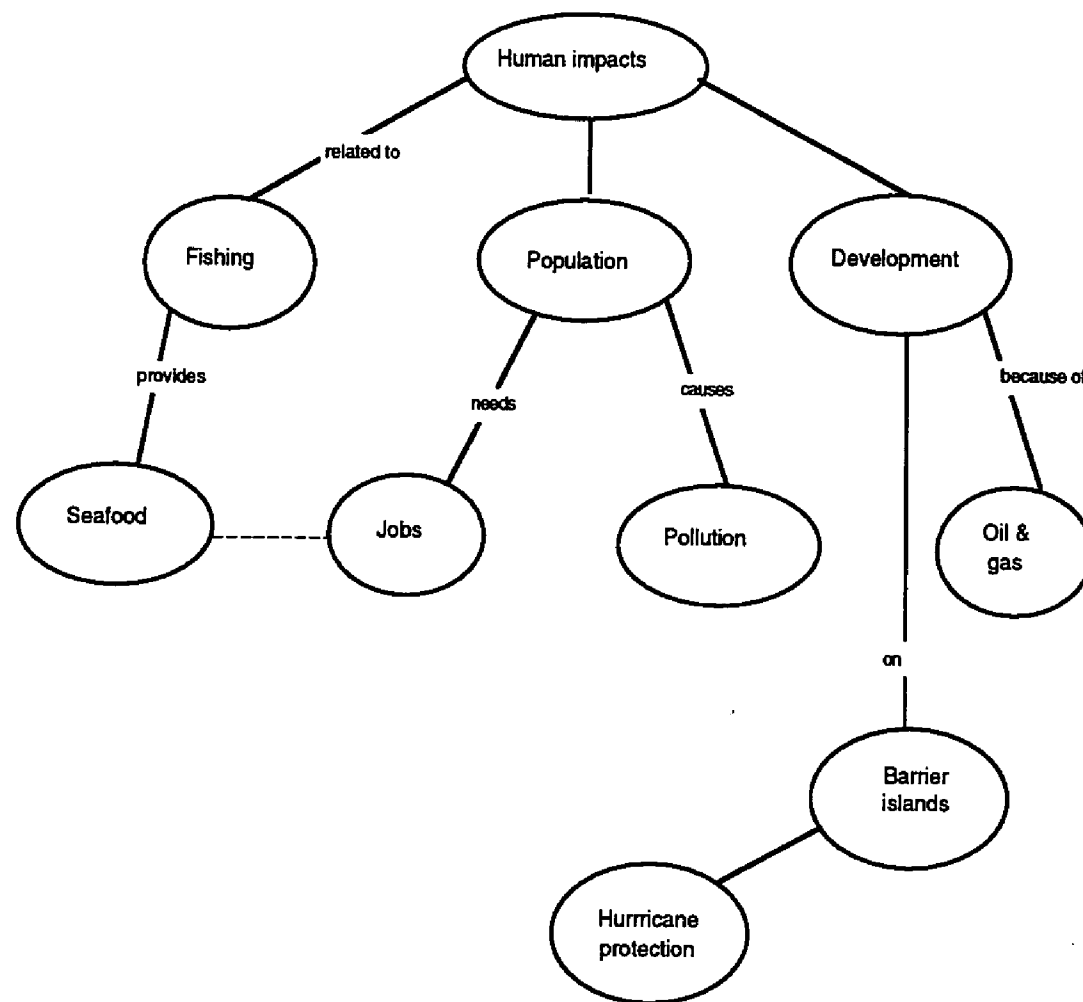


Figure F4.
Concept map: Jan from Urban Magnet High.

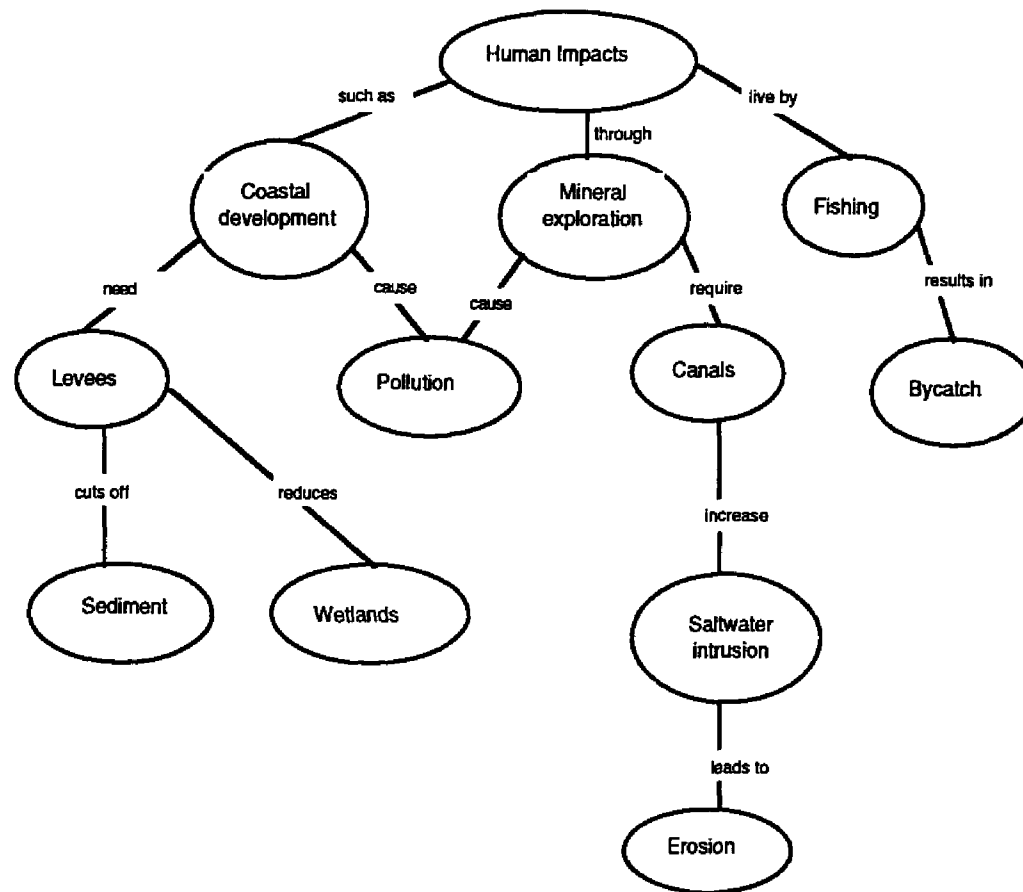


Figure F5.
Concept map: Ned from Urban Magnet High.

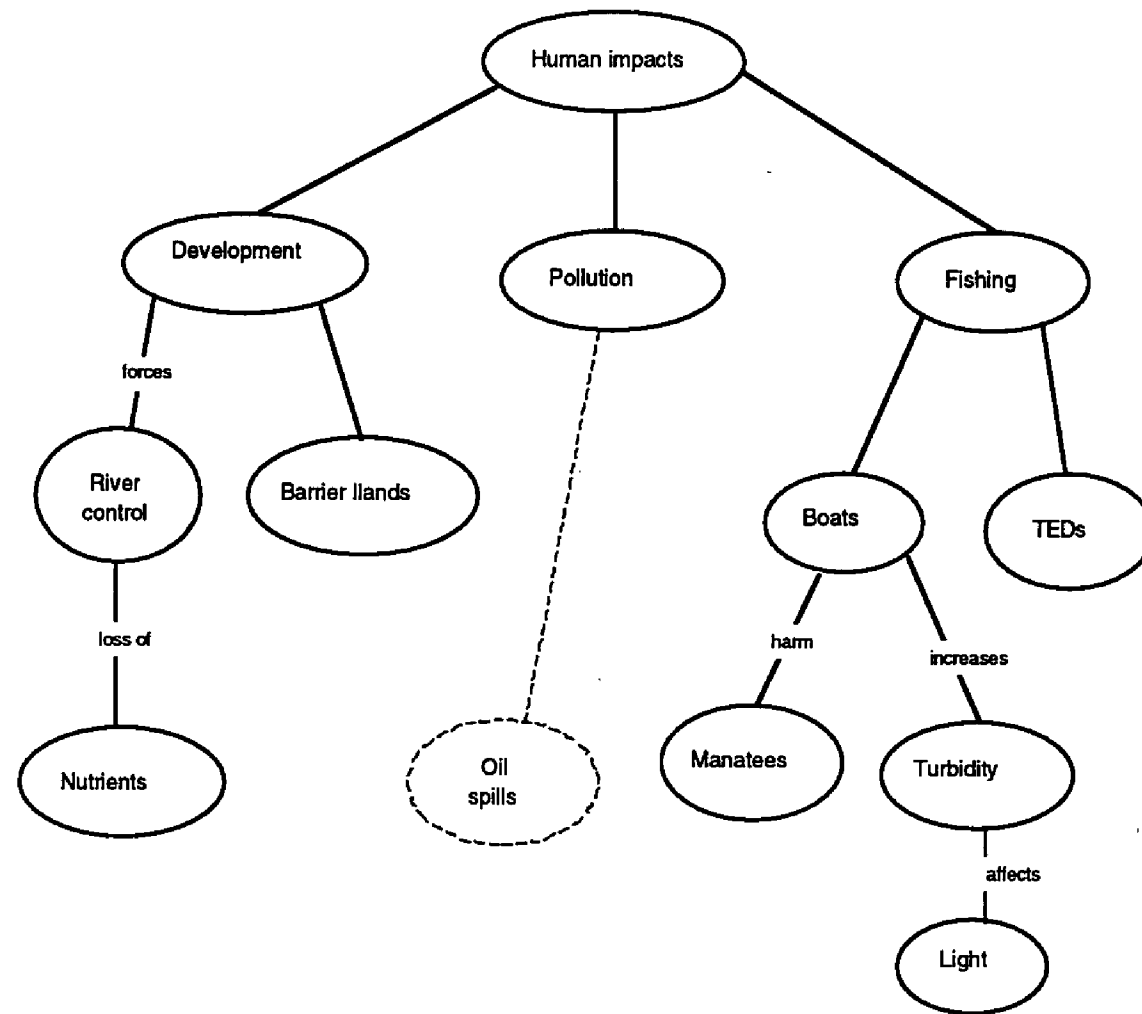


Figure F6.
Concept map: Sam from Urban Magnet High.

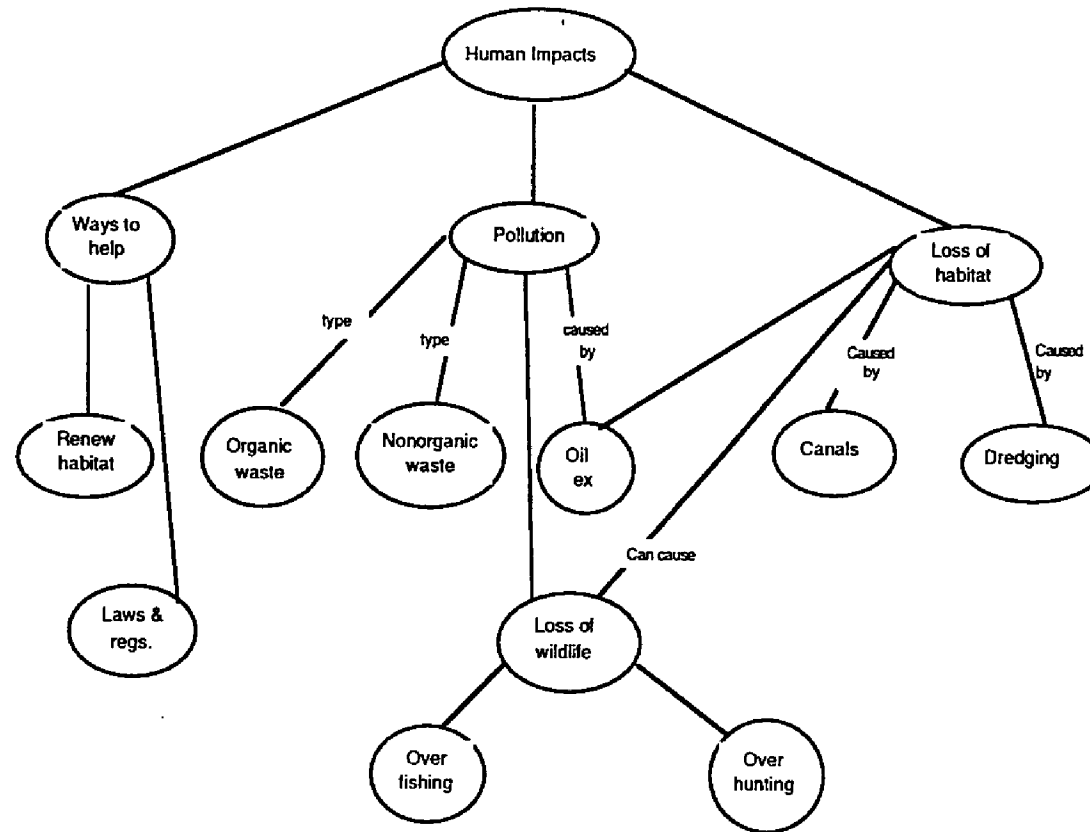


Figure F7.
Concept map: Ann from Suburban Magnet High.

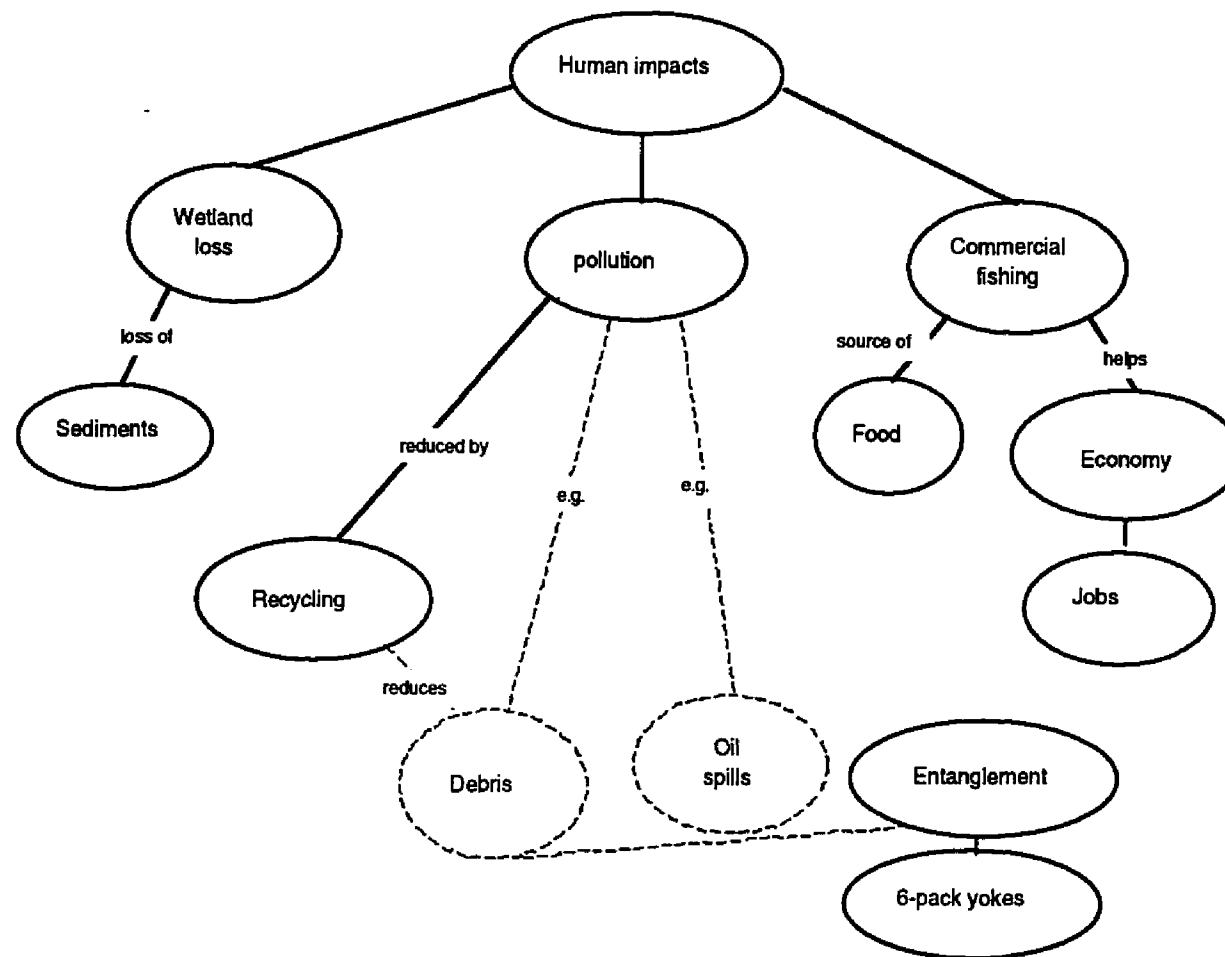


Figure F8.
 Concept map: Barb from Suburban Magnet High.

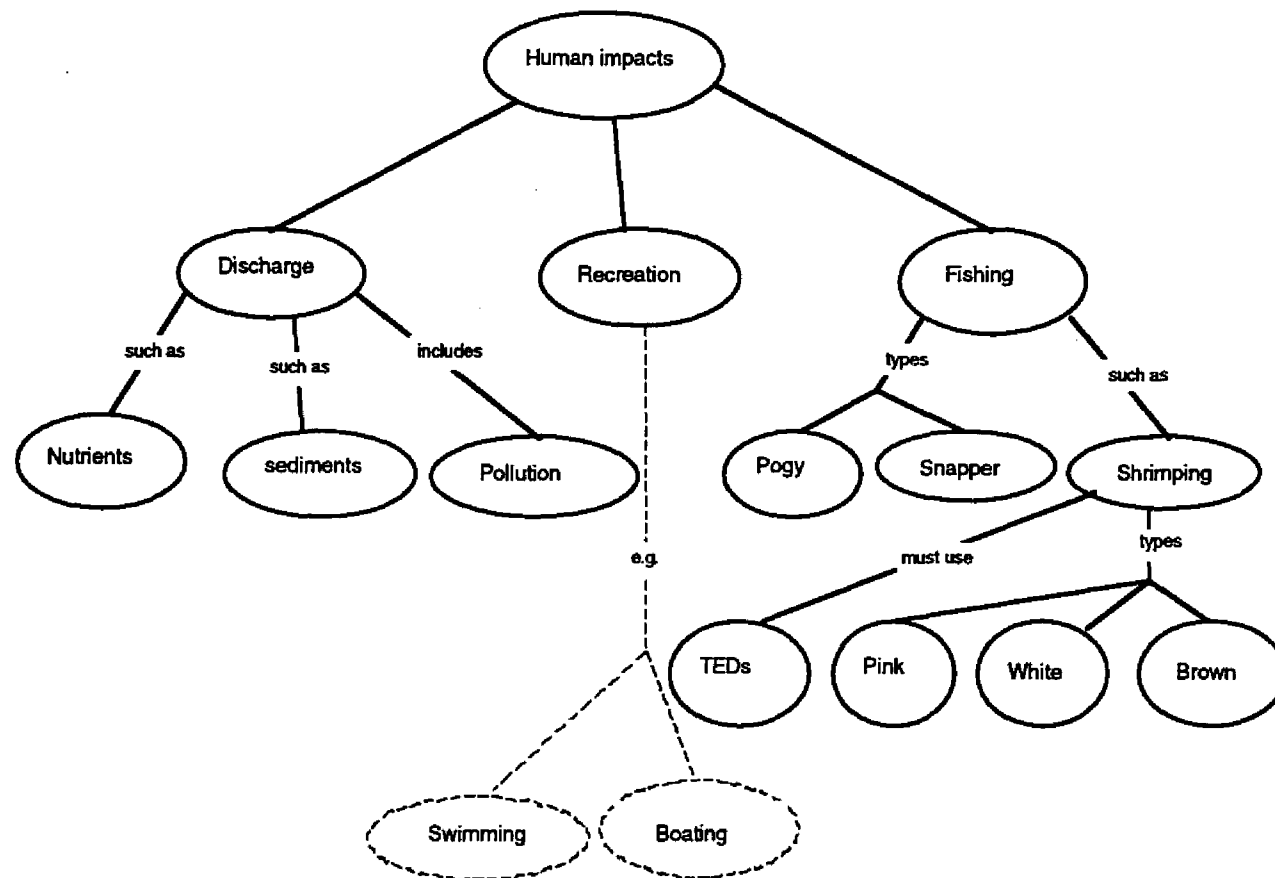


Figure F9.
Concept map: Carrey from Suburban Magnet High.

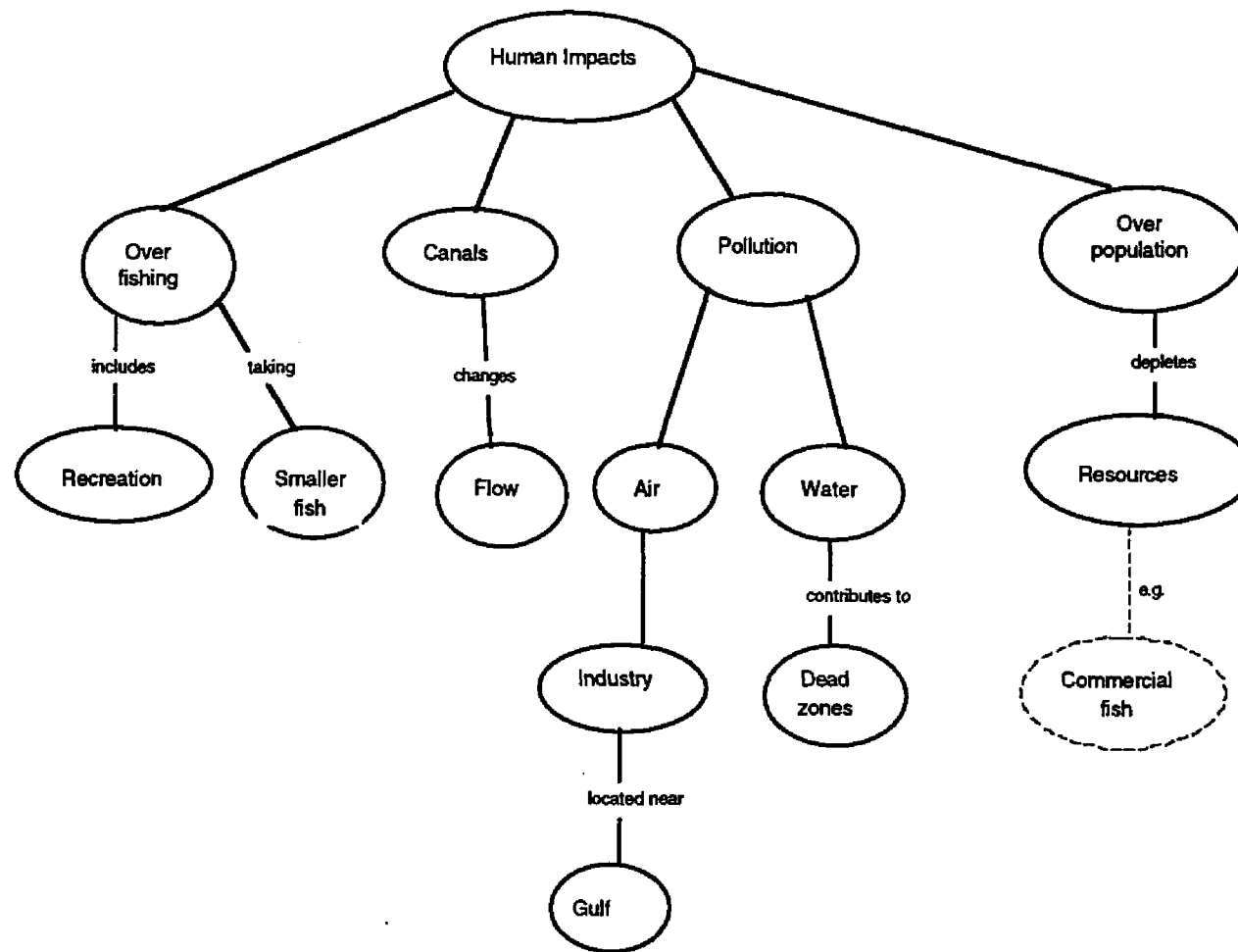


Figure F10.
Concept map: Jean from Suburban Magnet High.

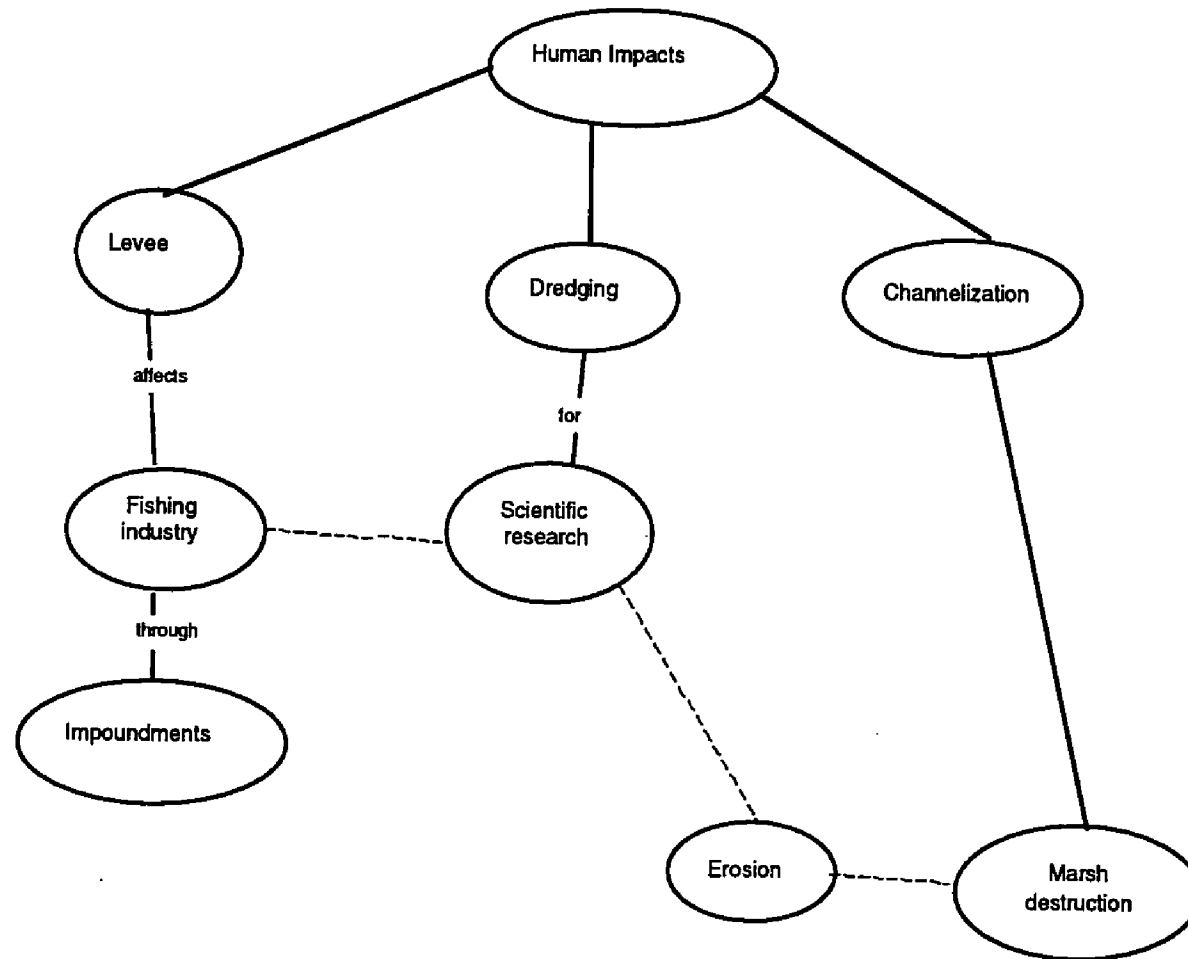


Figure F11.
Concept map: Jim from Suburban Magnet High.

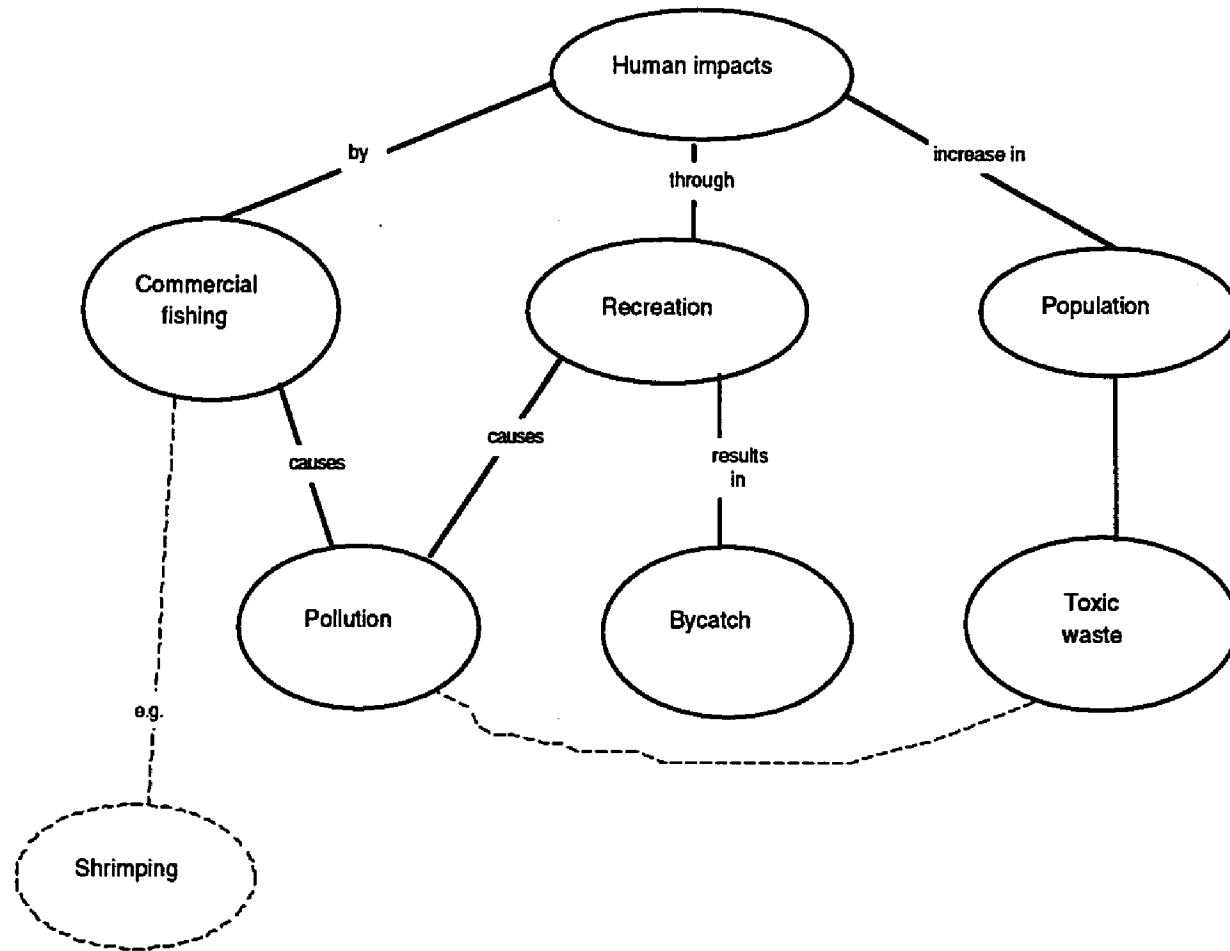


Figure F12.
Concept map: Mary from Suburban Magnet High.

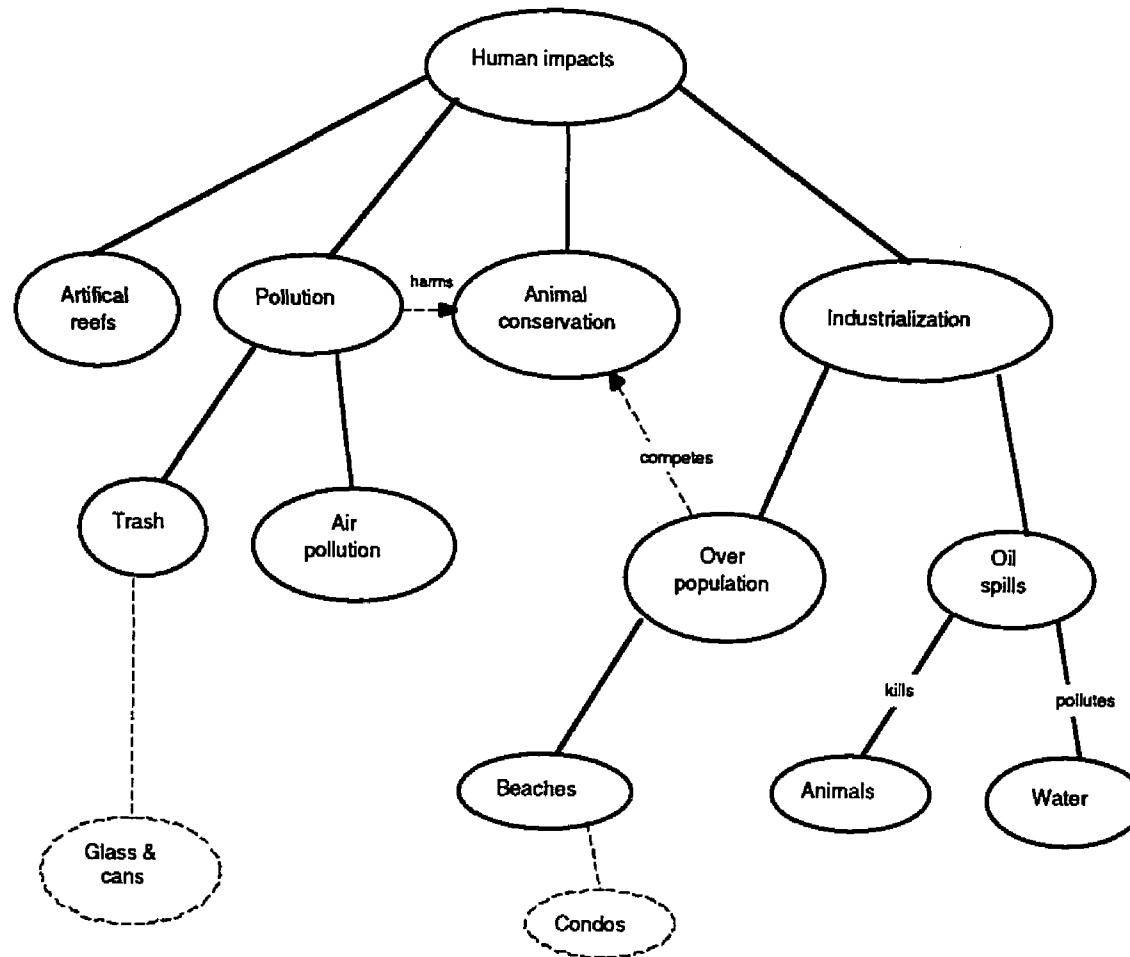


Figure F13.
Concept map: Donna from Rural High.

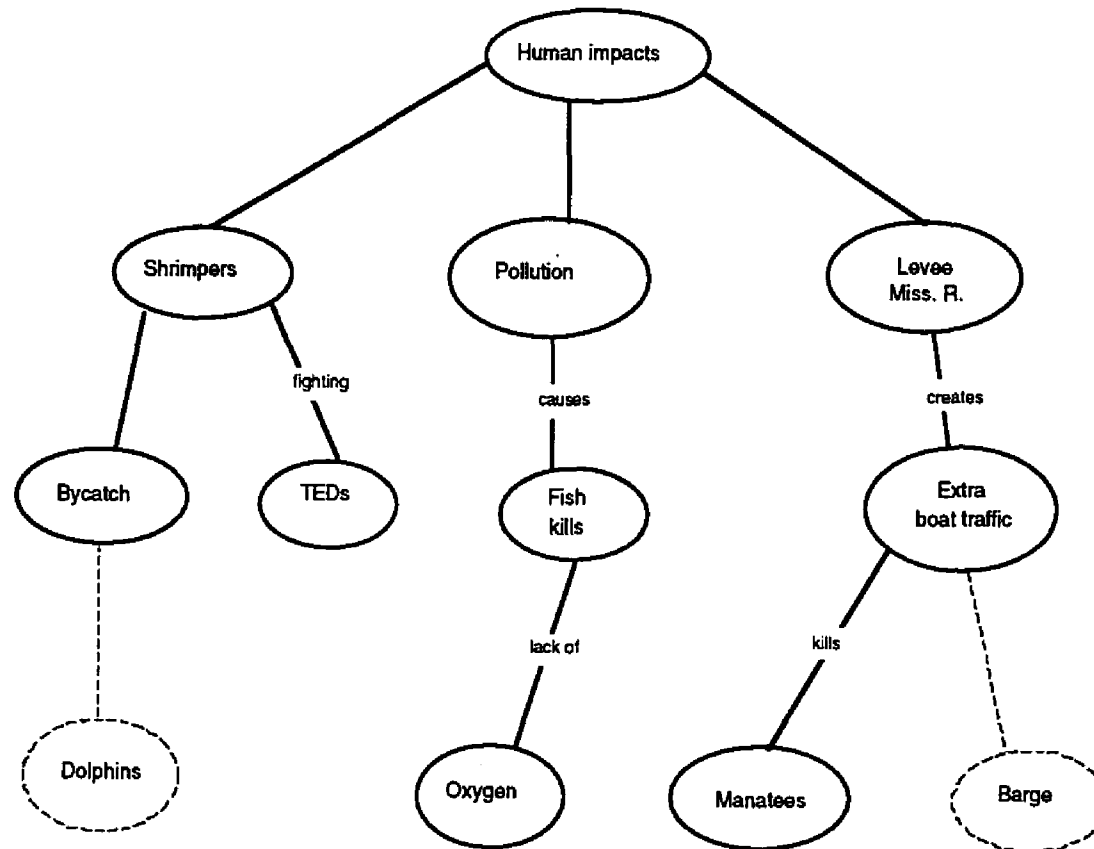


Figure F14.
Concept map: Don from Rural High.

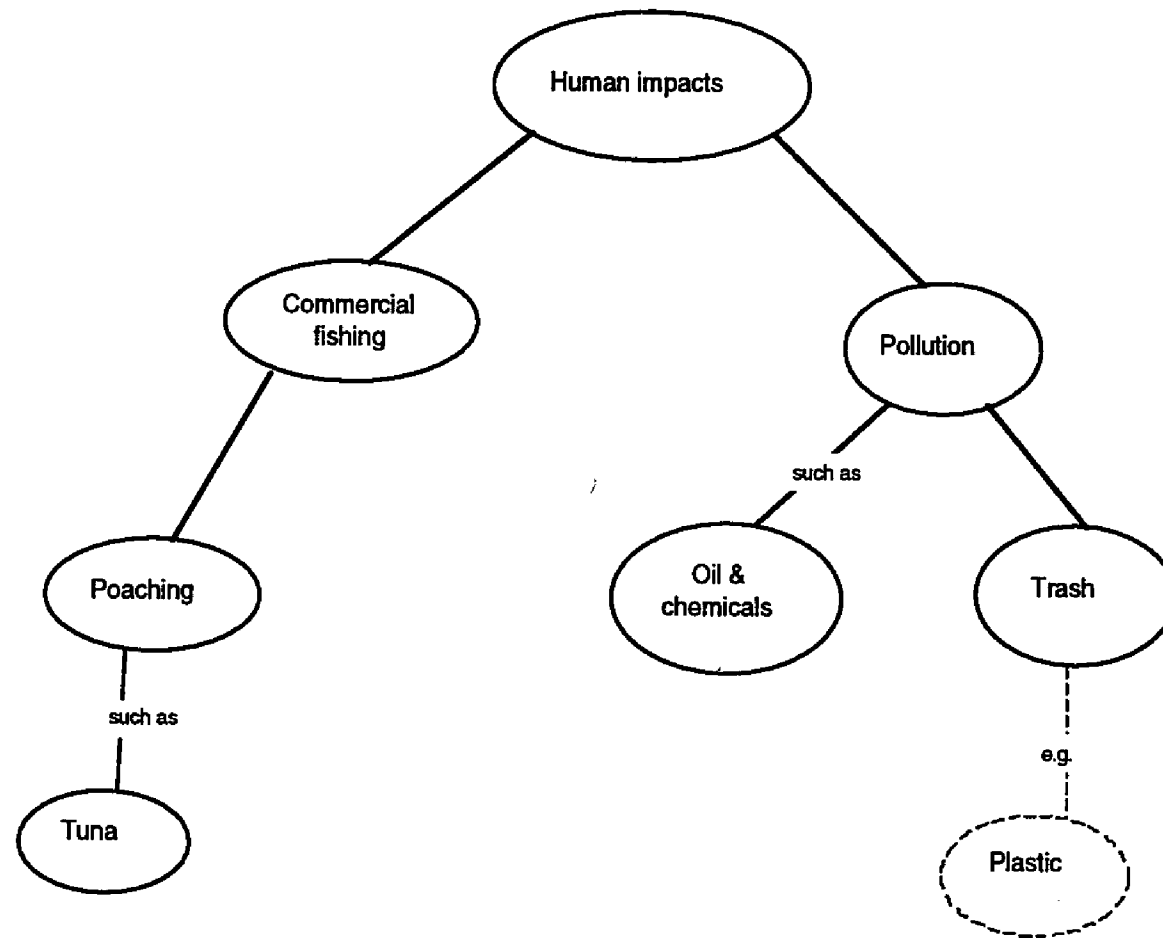


Figure F15.
Concept map: George from Doyle High.

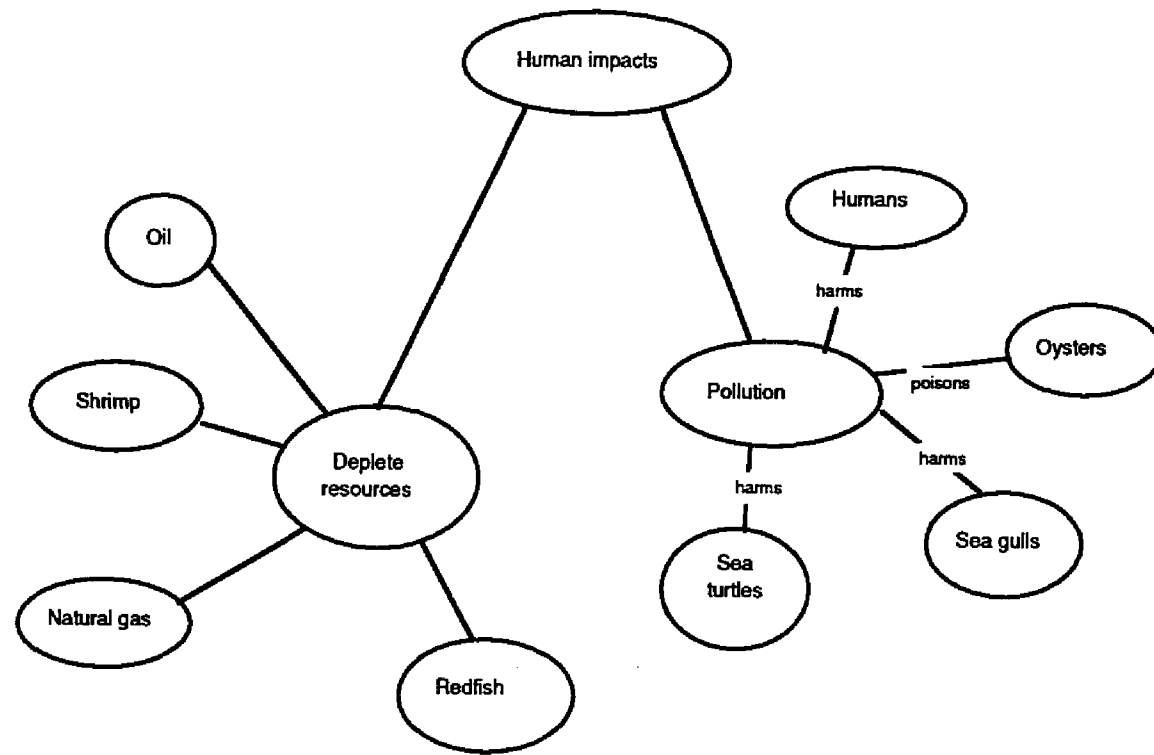


Figure F16.
Concept map: John from Rural High.

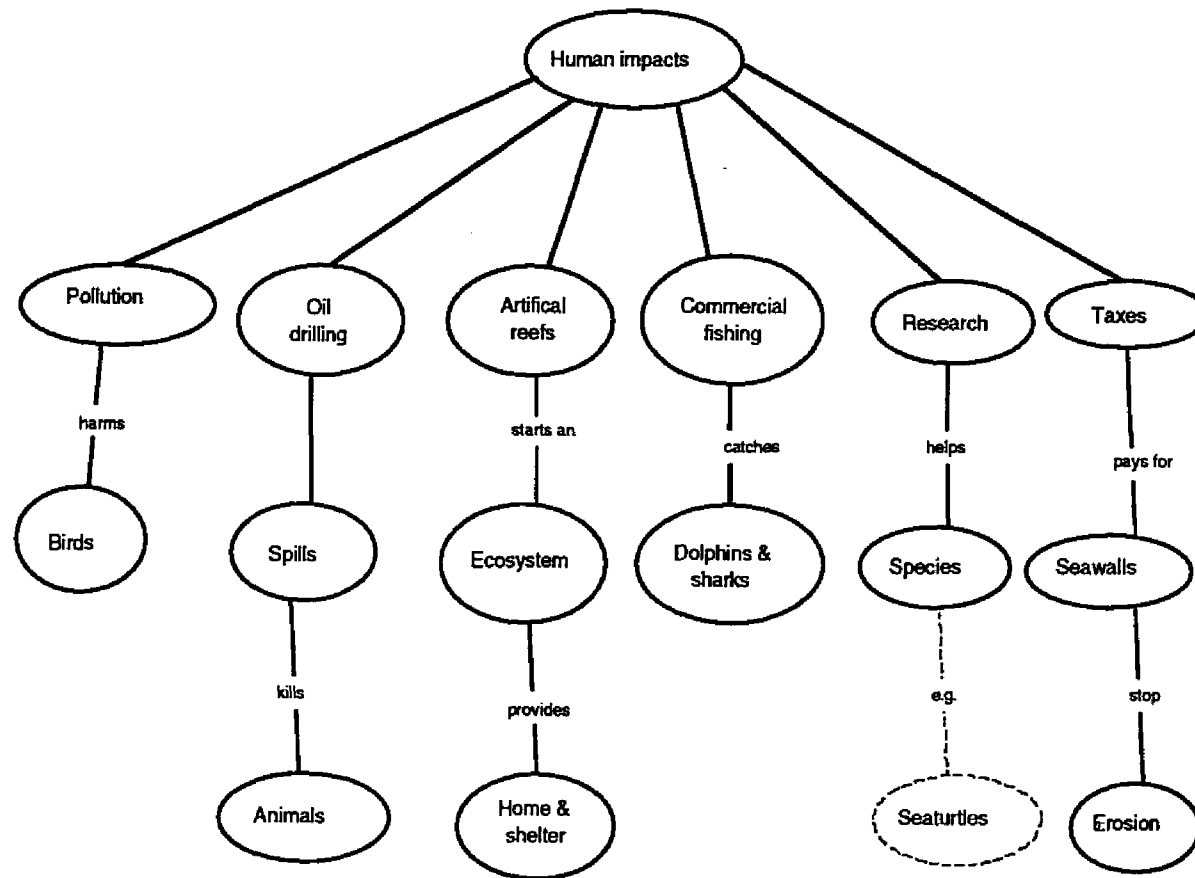


Figure F17.
Concept map: Sabrina from Rural High.

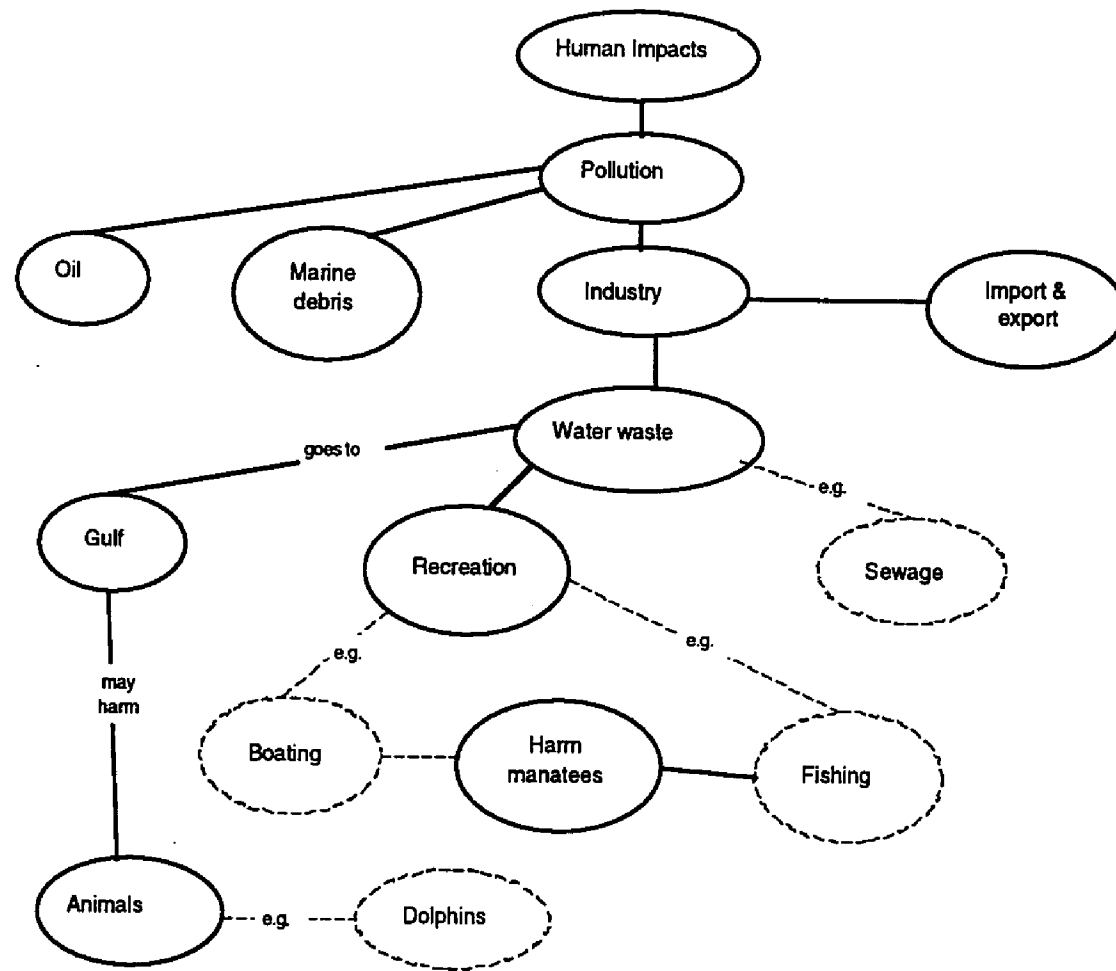


Figure F18.
 Concept: Ann from Small Town High.

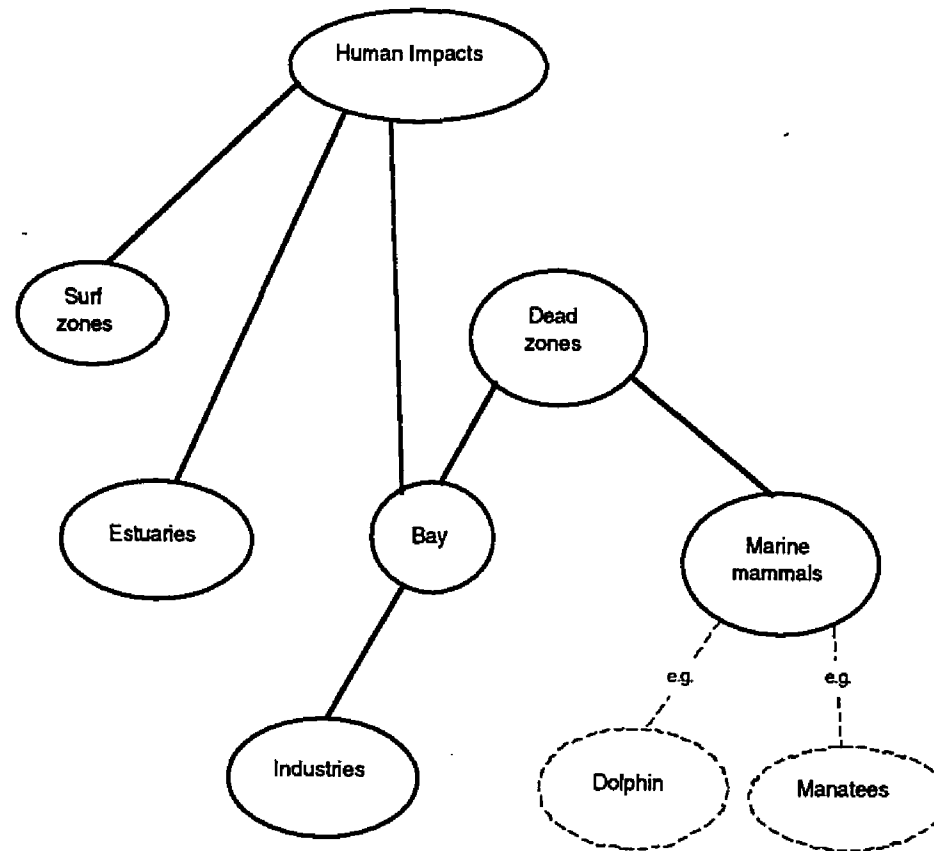


Figure F19.
Concept map: Diana from Small Town High.

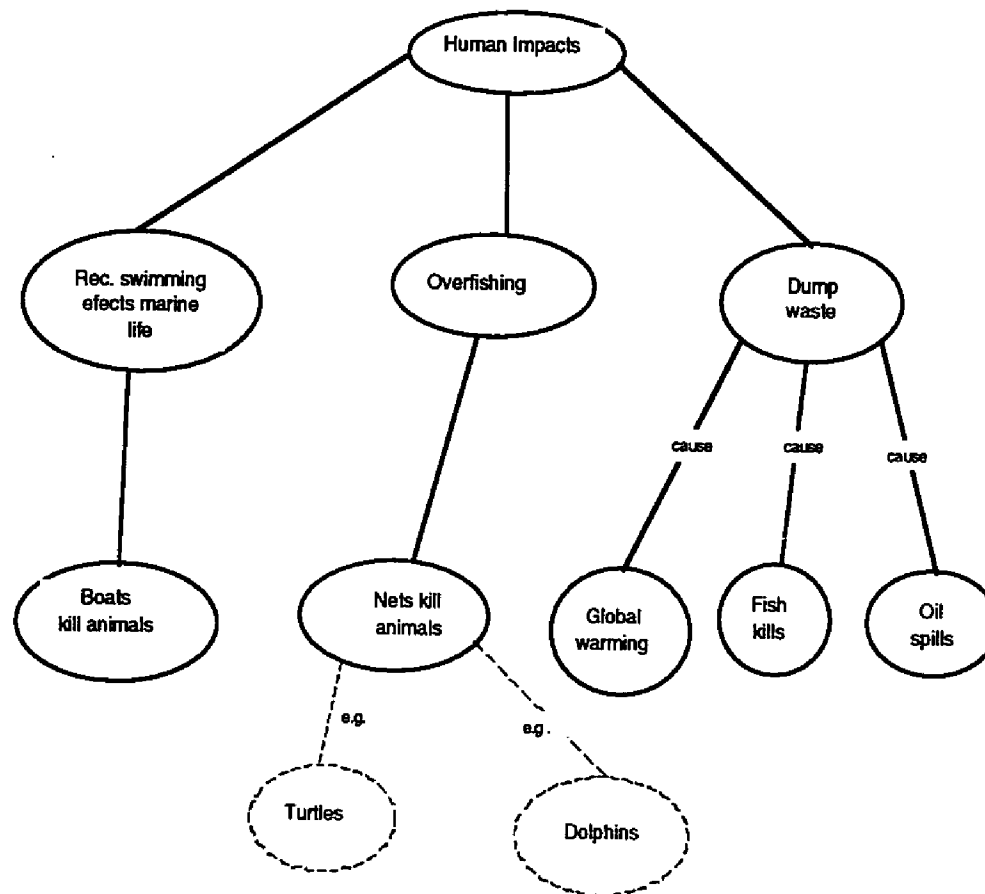


Figure F20.
Concept map: Matt from Small Town High.

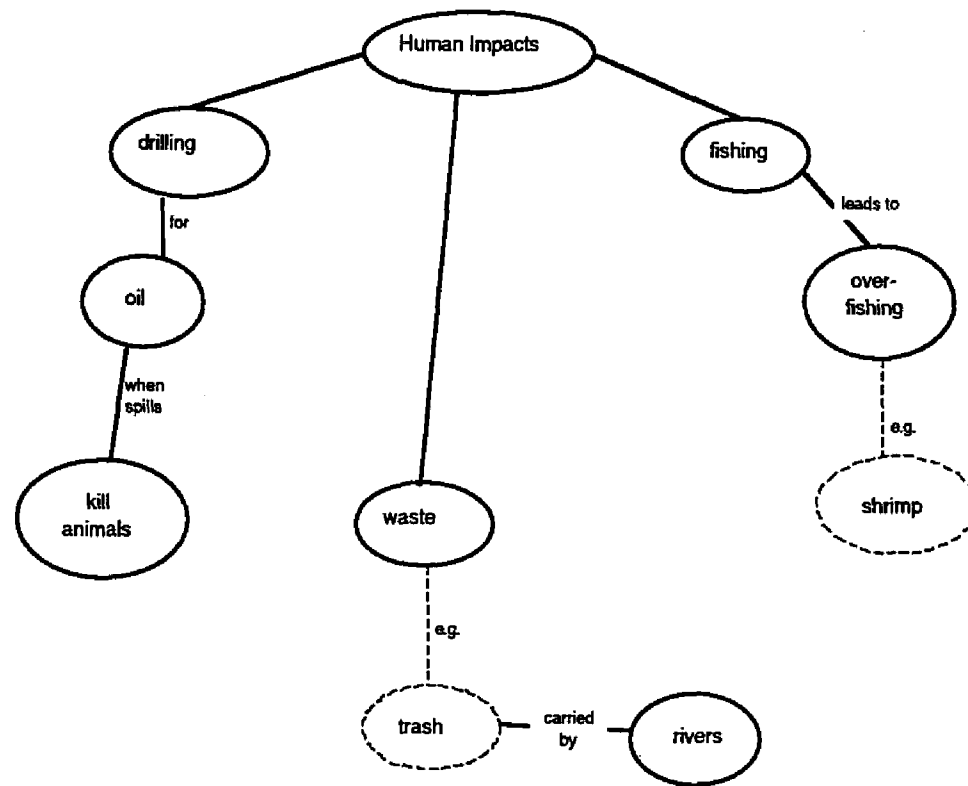


Figure 21.
Concept map: Sam from Small Town High.

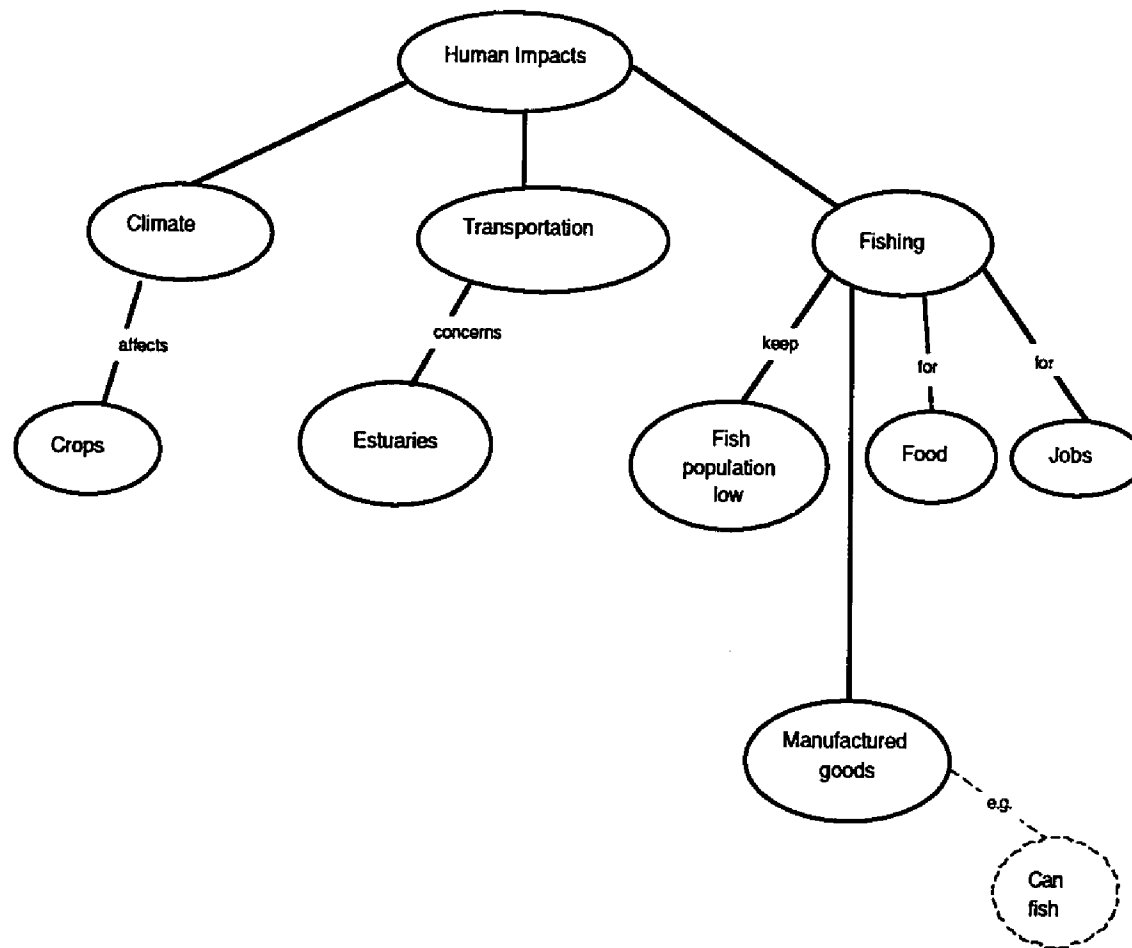


Figure F22.
Concept map: Tom from Small Town High.

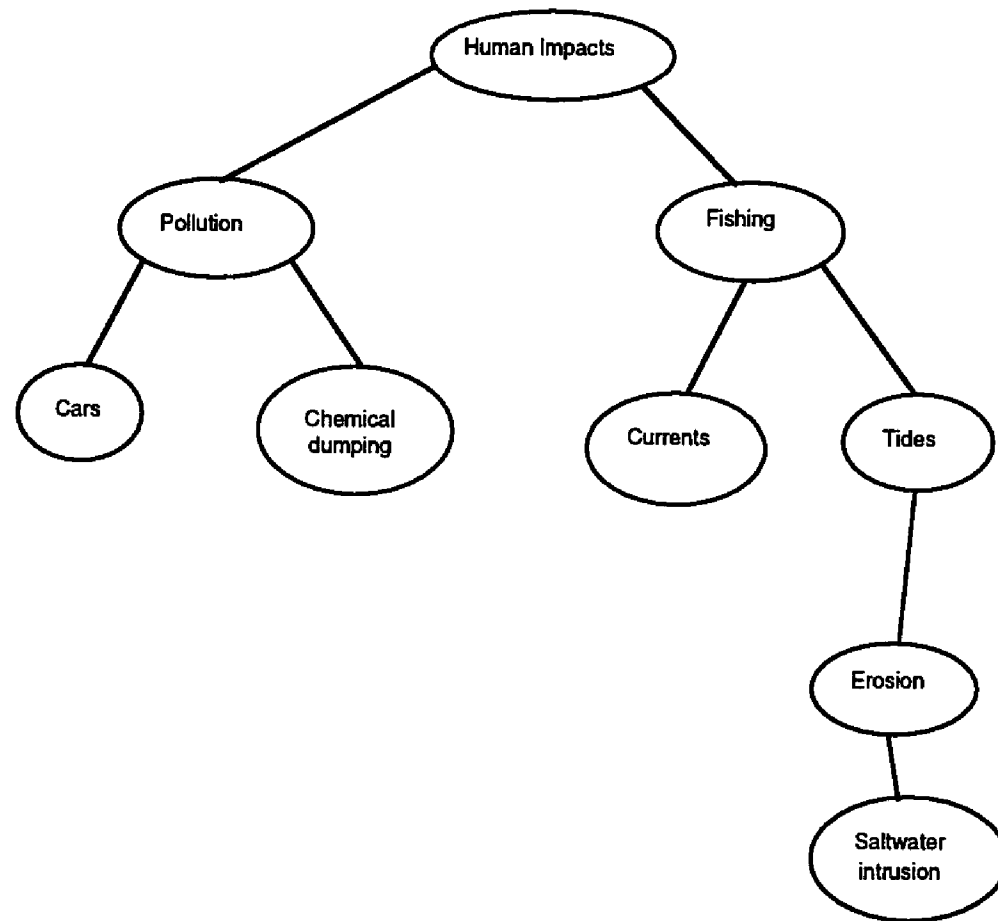


Figure F23.
Concept map: Mickey from Hammond High.

VITA

John Trowbridge was born at Camp Lejeune, North Carolina July 25, 1954. Being in a military family, he had an opportunity to live in many places such as Washington, D.C.; Long Island, New York; and Oceanside, California. He returned several times to Camp Lejeune, North Carolina. By the seventh grade he had developed a strong interest in natural sciences, especially in marine biology.

He attended the University of North Carolina at Wilmington (UNC-W) and received a Bachelor of Science degree in Marine Biology. In college a second interest in science education developed. After working two years as a research technician at the Cape Fear Estuarine Laboratory of North Carolina State University he returned to UNC-W to finish getting his teaching certificate. Three years of teaching junior high school turned him back to marine biology and he returned to UNC-W to complete a Master of Science degree in marine biology. Here he met Dr. Joel Mintzes, a recognized science education researcher. This was a fruitful collaboration in terms of his education and development of a research program. Two more years of teaching were undertaken in order to finish the degree.

John took a unique position that became available in Louisiana to combine education and marine sciences. The decision to work at the Louisiana Universities Marine Consortium had attached to it a five-year commitment and then to be followed by science education and fisheries at the doctoral level. Louisiana State University and its science education professors fortunately meet those needs.


DOCTORAL EXAMINATION AND DISSERTATION REPORT


Candidate: John E. Trowbridge

Major Field: Curriculum and Instruction




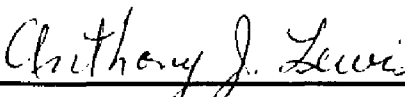

Title of Dissertation: Gulf Literacy: A Marine Science-based Model of Scientific Literacy

Approved:


Major Professor and Chairman


Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

September 22, 1995